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AIR POLLUTION CONTROL ASSOCIATION

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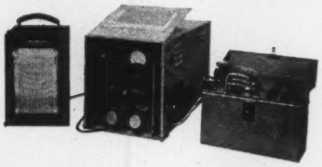
Chemical methods of analyzing air pollutants are always slow and inaccurate in low ppm range. Batch samples miss peak concentrations. □ Then there's the CEC vacuum sampling Titrilog. It monitors all oxidizable sulfur compounds directly and continuously with standard sensitivity to less than 1/10 ppm. Modified, it will measure to ten ppb! □ Sixty pounds light, three cubic feet small, this tough little Titrilog works best on the run—gives fast, *complete* concentration profiles moving at 30 MPH. □ Call your nearest CEC office or write for Bulletin CEC 1810-X2.



Analytical & Control Division

CEC

CONSOLIDATED ELECTRODYNAMICS
PASADENA, CALIFORNIA • A SUBSIDIARY OF BELL & HOWELL

IF YOU WANT SUPERIOR PRECIPITATOR PERFORMANCE

A precipitator is a lifetime purchase. Once it is installed, you must live with it, whether you like its habits or not. Because of that Buell urges you to look for the following features when you are making the major investment represented by an electric precipitator.

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1. Custom designed, flexible—Buell helps you determine your precipitator needs, then designs a unit specifically for your requirements. Since Buell SF Precipitator sizes change by only 16" increments, you can get exactly the size you need, without compromise of size, space, and cost.

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3. Rugged construction—Simple, rugged construction gives you high efficiency, combined with negligible maintenance costs.

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4. Uniform gas distribution—Buell designs the entire gas system for its precipitators—including connecting flues with adjustable turning vanes if needed. In addition, at the inlet, special field-adjusting baffles ensure uniform flow across the entire face of the unit. Buell has complete laboratory facilities to determine dust or gas flow pattern with specially constructed three dimensional precipitator models.

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5. Fool-proof power supply—Buell silicon rectifiers are compact, lightweight, highly efficient. They need no maintenance—another reason for the top performance of a Buell SF Precipitator.

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8. Minimum maintenance—The common maintenance headache in most precipitators is frequent replacement of emitting electrodes. Because of rugged suspension and patented electrode design, Buell's 10-year replacement record in this critical area is under 2%.

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9. Effective rapping—avoids reentrainment—Buell mechanically raps one row of electrodes at a time, in a continuous cycle. Special pockets in collecting electrodes, and section-by-section rapping in the direction of gas flow, ensure against reentrainment.

You're sure to be pleased with the superior performance and minimum maintenance you'll get with a Buell SF Precipitator! Buell Engineering Co., Inc., Dept. 51L, 123 William St., New York 38, N. Y. electric precipitators · cyclones · bag collectors · combination systems · classifiers. **Member Industrial Gas Cleaning Institute**

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LETTERS to the EDITOR

Correction Noted

Editor:

It has been brought to my attention concerning the paper "Relationships Between 24-Hour Mean Air Quality Measurements and Meteorological Factors in Nashville, Tennessee" published in the *J. of the APCA*, Vol. 11, No. 10, pp. 483–9, October 1961, that there is an autocorrelation in data taken from consecutive days, particularly with respect to temperature, so that the 182 consecutive days used cannot be considered as independent samples. Thus there is interference with least squares validity. In order to eliminate this insofar as possible, the autocorrelation of temperature was computed. The results for various lags are indicated in the following table:

Temperature Autocorrelation
(Oct. 2, 1958–Apr. 1, 1959)

Lag (days)	Autocorrelation Coefficient
1	0.79
2	0.52
3	0.41
4	0.43
5	0.50
6	0.51
7	0.47
8	0.41

Since for a series this long an autocorrelation coefficient of 0.25 is significant at the 0.001 level, it is seen from the table that it is not possible to take every nth days observation where n is the lag required for the autocorrelation to reduce below 0.25, without reducing the number of observations, 182/n, to such a small number that no correlations of statistical significance may be found between air quality data and meteorological parameters.

It may be concluded that although there are physical bases for the relations between air quality and the meteorological variables of degree day (temperature), stability, and windspeed, there is doubt as to the relations and the amount of variance explained by these parameters because of the nonindependence of the data employed.

D. BRUCE TURNER, USWB
Meteorology Section
Laboratory of Engineering
and Physical Sciences
Division of Air Pollution

Secretary's Page

Trans-atlantic Conference

Readers of the JOURNAL will recall the Secretary's Page of June 1960 entitled "International Flavor." This described the background and board policy with respect to international affairs.

One of the most ambitious undertakings in connection with APCA's efforts along the lines of international co-operation culminated in the Trans-atlantic telephone conference between the National Society for Clean Air and a panel appointed by Dr. Edward R. Weidlein, Chairman of APCA's International Affairs Committee, on October 5. Arrangements were made for telecasting the APCA portion of the conference from the auditorium of the Mellon Institute, and this has now been reproduced as a half-hour film. Several prints have been made and are available upon request to any interested individual or group through APCA headquarters. This film is an excellent educational vehicle for informing APCA members and the general public about the problems and approaches to their solutions in both the United States and Great Britain.

Honors and Awards

Dr. Louis C. McCabe, Chairman of the Honors and Awards Committee, wishes to remind members that he is actively soliciting nominations for awards to be presented in 1962 at the Annual Meeting in Chicago. The two main awards are the Frank A. Chambers and Richard Beatty Mellon citations. The Frank A. Chambers award established in 1954 may be made each year to a member or nonmember of APCA for outstanding achievement in the control of air pollution. The Richard Beatty Mellon award established in 1955 may be made each year to honor an individual whose contribution of a civic, administrative, technical, or other nature has aided substantially the cause of air pollution control. In addition to these two awards members are encouraged also to recommend candidates for honorary membership. Persons recommended for this type of award should be particularly eminent in the field of air pollution control or who have rendered especially meritorious service to the Association.

The recipients of the Frank A. Chambers and Richard Beatty Mellon awards in the past years have been extremely distinguished scientists and citizens who have been the pioneers in the field. The awards ceremony has been a highlight of the Annual Meeting each year. Nominations may be sent to the other committee members in addition to Dr. McCabe who are: Dale H. Hutchison, Charles W. Gruber, Herbert C. McKee, and Dr. L. V. Cralley.

The Air Famine

Editor:

Having viewed the television program "CBS Reports" on The Water Famine, seen in Erie on October 19, 1961, I feel that much has been accomplished by APCA, and the many technical committees working on this equally vital commodity, air.

It has been proved conclusively that "one can go without water for an average of 72 hours without suffering ill effects." How long can one wait to take a breath, while waiting for the air to clear.

The thought occurred to me that "CBS Reports" should do a feature on The Air Famine, with APCA providing the necessary technical assistance to inform the man on the street of what APCA and the Public Health Service are doing.

In some cases, the "Smoke Inspector" is despised more than the municipal dog catcher, people usually love their dogs.

ROY HOLLAND, Chief
Bureau of Smoke Abatement

Cleaner Air Week

Mr. Charles N. Howison, Chairman
Cleaner Air Week Committee, APCA
2901 Union Central Building
Cincinnati 2, Ohio

Dear Mr. Howison:

It is a pleasure to endorse the objectives of Cleaner Air Week, October 22–28. Since 1949, this annual compaign has been helping to alert the

(*Continued on p. 589*)

JOURNAL OF THE AIR POLLUTION CONTROL ASSOCIATION

FOUNDED 1907

A Monthly Journal
Devoted to
Air Purification

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Assistant Editor: Pat Martin

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The Editor welcomes writers interested in air pollution problems and encourages them to use the pages of this journal for the expression of their opinions. But neither he nor the Association assumes responsibility for the validity of the opinions expressed herein.

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THE 1962 APCA EXPOSITION

55TH ANNUAL MEETING

Chicago-Sheraton Hotel, Chicago, Illinois

May 20–24

- ***Each year the APCA holds its annual meeting and exposition in various centers of industry, this year Chicago has been chosen as the meeting headquarters. It is important to recognize that in scope the objectives are to:***
    - ***Furnish a common ground for the exchange of technical information.***
    - ***Stimulate development progress.***
    - ***Document the year-to-year progress in the constantly expanding field of Air Pollution Control.***
- ***A high calibre of Air Pollution Control specialists from industry and government are expected to attend. This is because of the unprecedented interest in new control techniques devised to meet the requirements of Air Pollution Control.***
- ***Exposition represents an unduplicated opportunity to communicate newly developed capabilities and PRODUCTS to an audience which will not be congregated again under one roof in 1962.***

ALL ADS FOR THE APRIL CONVENTION ISSUE OF THE *JOURNAL*

DUE BY FEBRUARY 28.

The EFFECTS of a Low Ethylene CONCENTRATION on the Growth of COTTON*,†

WALTER W. HECK, E. GERALD PIRES, and **WAYNE C. HALL,** Texas A. and M. College, College Station, Texas

Ethylene was first identified as a major air pollutant from studies on damage to cotton and other crops growing in the vicinity of an industrial polyethylene plant located on the Gulf Coast of Texas.[1] Analysis of air samples gave ethylene concentrations ranging from 0.04 to 3.0 ppm depending on wind direction, velocity, and distance from the industrial plant. Fields of cotton down wind and within a mile of the emanating source gave almost 100% loss of yield. Field symptoms included leaf abscission, scattered seedling death, vine-like growth habit, and abscission of squares.

The effects of ethylene on plant growth have been extensively studied by Crocker and co-workers at the Boyce Thompson Institute for Plant Research.[2] Early research was stimulated by requests to determine the causative agent of injury to greenhouse plants. Initial investigations traced this injury to artificial illuminating gas containing ethylene as a major constituent. These early works led to more detailed studies of the effects of ethylene on a great number of plant species. Plants differ in their sensitivity but most species studied by these early workers showed some response to low concentrations of ethylene. Typical symptoms include: leaf epinasty, arrestment of growth, loss of chlorophyll, abscission of plant parts, proliferation of tissue (including stimulation of adventitious roots), and variations in cellular metabolism. For the most part these early experiments were of short duration, 12 to 106 hours, and involved no air exchange. One series of experiments using a continuous air flow and gas change was carried out with very low concentrations of ethylene, 40 and 100 ppb. These were run for 27 days and a 25 to 50% reduction in height was noted in the five species studied. No severe plant injury or death was reported by these workers in their studies.

Ethylene, unlike other gaseous air pollutants which are toxic to plant tissues, can be considered a physiologically active gas in that it produces growth effects at physiological concentrations. Many of these effects are normal for plant growth but are hastened by the addition of low concentrations of ethylene gas—thus we speak of ethylene as hastening senescence of plant tissues. Ethylene is also a natural product produced by living plant tissues. Experimental results[1, 2] show that ethylene is released by many if not all plants, during aerobic respiration. Field studies[3] indicate the normal presence of ethylene in low concentrations over fields of many different grasses.

Thus ethylene, as an air pollutant, has many diverse sources: as a blow-off gas from the cracking of natural gas in petrochemical plants; as a waste product from the incomplete combustion of most organic substances; and as a natural emanation from most, if not all, growing plants. Ethylene then must be present, at some level, in all air. Because of its known effects on plant growth, additional information is needed on the effects of given concentrations throughout the growth period of various plants grown under controlled conditions.

The present study was designed to determine the effects of a low level of ethylene on cotton grown under controlled conditions, during the entire growth period of the plants.

Plant Growth Chambers

The growth of plants under controlled conditions requires special growth chambers or greenhouses. Owing to variability of light under greenhouse conditions a bioclimatic chamber was required in which the major environmental variables could be closely controlled. For various reasons no commercially available or currently used chambers seemed to meet our specifications. Although many ideas were obtained from a currently operating plant growth chamber on this campus,[4] there are sufficient structural modifications in the present chambers to warrant a fairly detailed description of the chamber construction and controls used. These chambers were designed as gas-tight compartments with controls for the following conditions: light, temperature, humidity, water, air flow, and gas concentration.

Chamber Construction

Two plant growth chambers were constructed on an 8 x 8 foot table. Details of chamber number two are outlined in Fig. 1. These 4 x 4 x 6 foot chambers have a 2 x 4 inch wood framework with a 3/4 inch plywood floor. The two sides and top are of 1/8 inch "R" grade plexiglas inserted into the grooved 2 x 4 inch framework. Before inserting the plexiglas siding, the grooves were filled with plexiglas cement. This was done to insure a strong bond and a gas-tight seal. All wood joints were heavily glued before final union and heavy gauge screws were used to draw all joints tightly together.

Entrance into the chambers is through a 30 x 36 inch opening in the free side of the chamber. The edges of this opening were drilled for 1/4-inch bolts, which were inserted with the head inside the chamber. A 1 1/2 inch width of 1/2 inch plexiglas was then installed as a framework behind the edge of the chamber opening. The bolt heads were embedded into this 1/2 inch plexiglas with plastic glue. A strip of 1/2 inch "closed cell" rubber gasket material was drilled to fit over each protruding bolt. This gasket maintains a gastight seal when the 1/8 inch plexiglas door is bolted against it.

The transition pieces are of 24 gauge galvanized metal with all metal unions soldered and held with sheet metal screws. An inch lip on the chamber side permits a tight seal by use of 3/4 inch

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* Presented at the 54th Annual Meeting of APCA, Commodore Hotel, June 11–15, 1961, New York, New York.

† This investigation was supported by Research Grant RG 6398, National Institutes of Health, U. S. Public Health Service.

permagum cords (a nonhardening, nonreactive, sealer) and one inch sheet metal screws. These transition pieces fit snugly into the five inch diameter galvanized duct work shown in Fig. 1.

After construction of the chamber, all corners and joints were rechecked and covered with permagum then all wood and metal parts were given three coats of a hard finish white gloss enamel.

The chamber proper is insulated with a second layer of $^1/_8$ inch plexiglas mounted to give a one inch dead air space between the two plexiglas sheetings. All metal ductwork is covered with $1^1/_2$ inch fiberglass insulation.

Lighting

The light bank is a 6 x 8 foot framework of 2 x 6 inch pine covered with perforated sheet metal. The entire framework is painted with a white enamel. This bank was built to cover both chambers and consists of 34-F96T12/CW/XHO Ken Rad fluorescent tubes plus six 150-watt incandescent bulbs. These lights are on four separate circuits, each circuit with a time clock. Thus four different light intensities can be maintained or dawn and evening conditions may be simulated by placing the time clocks at different on-off settings. Highest light intensities are maintained when the air temperature around the bulbs is kept between 75 and 85°F. The following light intensities, at the indicated height above the chamber floor, are maintained within the center 12 square feet of the chamber under a full light load: chamber floor—1600 to 2000 fc; two foot level—2300 to 2800 fc; four foot level—3400 to 4200 fc. The outside corners showed a rather uniform intensity regardless of height while the center area of the chambers gave intensities closely correlated with distance from lights.

Air Flow

Galvanized five inch ductwork was used throughout for air movement. All duct unions were made with sheet metal screws, sealed with solder and taped with a two inch heavy weight tape before insulation with the fiberglass. For control of air speed and direction of flow, four pairs of $^3/_4$ inch wooden flanges (eight inch OD, five inch ID) were inserted into the ductwork. One pair of flanges on the inlet air duct is not shown in the figure. The flanges were screwed into the ductwork and sealed on both sides with permagum. Special $8^1/_4$ inch diameter discs from $^1/_8$ inch masonite are inserted between these flanges and a three inch width of rubber tubing is stretched over the paired flanges plus the disc to give a gas-tight seal. The discs are either solid, to stop air flow, or have a machined orifice for control and/or measurement of air flow.

Air flow can be varied by use of different discs in the flanges. For continuous intake and exhausting of air, the flange pair between the air inlet duct and the chamber exit duct is closed. For continuous recirculation of air, the flange pair on the inlet duct and the pair on the exhaust duct are closed. The insertion of discs with machined orifices allows for partial exhausting of air. Thus by varying orifice size almost any percentage of fresh air—from 0 to 100—can be maintained.

Air volume is controlled and measured by insertion of orifice discs at the flange pair in the inlet duct or just downstream from the blower. Static pressure pick-up rings have been installed just upstream and downstream from both of these flange pairs. These pick-up rings measure the static pressure on either side of the orifice and the pressure differential, as measured with a water manometer, is inserted into the following equation:

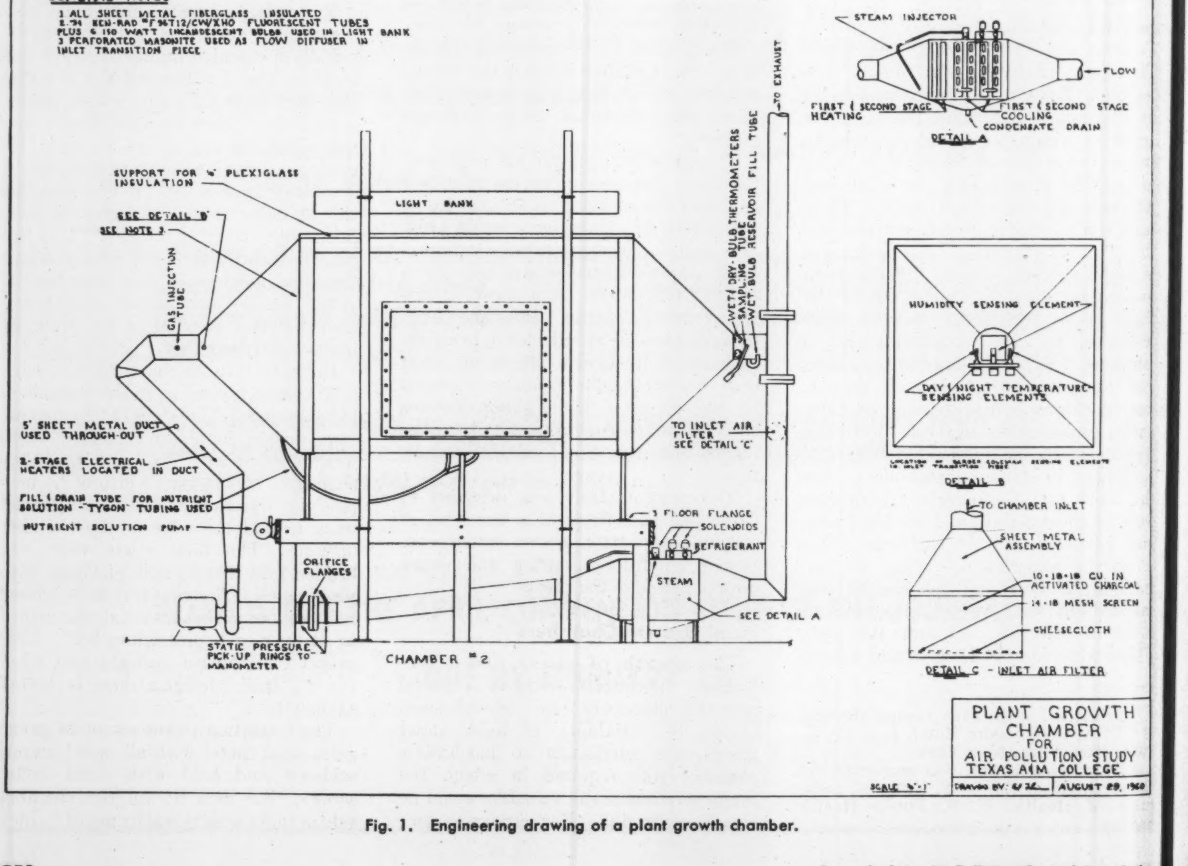
GENERAL NOTES
1 ALL SHEET METAL FIBERGLASS INSULATED
2. 34 KEN-RAD "F96T12/CW/XHO FLUORESCENT TUBES PLUS 6 150 WATT INCANDESCENT BULBS USED IN LIGHT BANK
3 PERFORATED MASONITE USED AS FLOW DIFFUSER IN INLET TRANSITION PIECE
STEAM INJECTOR
FLOW
FIRST & SECOND STAGE HEATING
FIRST & SECOND STAGE COOLING
CONDENSATE DRAIN
DETAIL A
TO EXHAUST
SUPPORT FOR ⅛" PLEXIGLASS INSULATION
SEE DETAIL 'B'
SEE NOTE 3
GAS INJECTION TUBE
LIGHT BANK
WET & DRY-BULB THERMOMETERS
SAMPLING TUBE
WET-BULB RESERVOIR FILL TUBE
HUMIDITY SENSING ELEMENT
DAY & NIGHT TEMPERATURE SENSING ELEMENTS
LOCATION OF BARBER COLEMAN SENSING ELEMENTS IN INLET TRANSITION PIECE
DETAIL B
5" SHEET METAL DUCT USED THROUGH-OUT
2-STAGE ELECTRICAL HEATERS LOCATED IN DUCT
FILL & DRAIN TUBE FOR NUTRIENT SOLUTION - "TYGON" TUBING USED
NUTRIENT SOLUTION PUMP
TO INLET AIR FILTER SEE DETAIL 'C'
3 FLOOR FLANGE
SOLENOIDS
REFRIGERANT
STEAM
SEE DETAIL A
ORIFICE FLANGES
STATIC PRESSURE PICK-UP RINGS TO MANOMETER
CHAMBER #2
TO CHAMBER INLET
SHEET METAL ASSEMBLY
10 × 18 × 18 CU. IN ACTIVATED CHARCOAL
14 × 18 MESH SCREEN
CHEESECLOTH
DETAIL C - INLET AIR FILTER
PLANT GROWTH CHAMBER FOR AIR POLLUTION STUDY TEXAS A&M COLLEGE
SCALE ½"=1'
DRAWN BY:
AUGUST 29, 1960

Fig. 1. Engineering drawing of a plant growth chamber.

$$L = k\sqrt{P}$$

Where L is liters per minute of air flow, P is the pressure differential in inches, and k is a constant which will vary with each orifice diameter. This constant includes duct diameter, orifice diameter, conversion factor from cubic feet per minute to liters per minute, density of air at a given temperature, and the delivery coefficient.

At the present time, air flow is maintained by a one-half hp continuously operating Buffalo Forge, Type E blower. The flange pairs in the inlet and exhaust ducts are open, the pair between the inlet duct and chamber exit duct is closed, and the pair downstream from the blower contains a two inch orifice disc. This orifice has given a consistent pressure differential of from $3^1/_{16}$ to $3^3/_{16}$ inches of water for an air flow of 2651 to 2713 liters per minute.

Air movement into and out of the chamber proper is facilitated by the pyramid shape of the transition pieces. In addition, even flow across the chambers and plants is maintained by a masonite baffle board inserted at the junction of the inlet transition piece and the chamber proper. This baffle has $^1/_8$ inch holes drilled on one inch centers and produces an even air flow through all parts of the chamber.

Gas Flow

The continuous injection of small but known amounts of a gas into an air stream is somewhat difficult. Two methods based on the use of calibrated capillary flow tubes are reported in the literature.[5, 6] Although both methods are temperature sensitive, the first method is extremely sensitive and we have obtained rather erratic results with temperature variations of 2 to 3°F in the laboratory. Under constant temperatures both of these methods are reliable and give results which are easily duplicated. However in our initial work with high air volumes and a relatively high gas concentration (0.6 ppm) we found the following method highly satisfactory, with little variability and good reproducibility.

A four mm OD glass tubing was calibrated, under room conditions (75°F), for five cc delivery. This five cc section was marked and the tubing cut about six inches below and above the mark. The calibrated tube was then connected to the left arm of a Y tube, a gas source to the right arm and tygon tubing, containing a soap solution, to the bottom. Gas is introduced and the tygon soap reservoir raised until the soap solution fills the junction of the Y tube. The gas passes through the soap solution and carries the soap bubbles into the calibrated flow tube. Once the tube is wet a pair of bubbles is allowed to form, the soap solution is lowered, and the time it takes the bubbles to move five cc is checked with a stopwatch. Thus the flow rate of the gas in cc per minute is readily obtained. Flow rates, using the above method, were kept within ±10% of a mean reading.

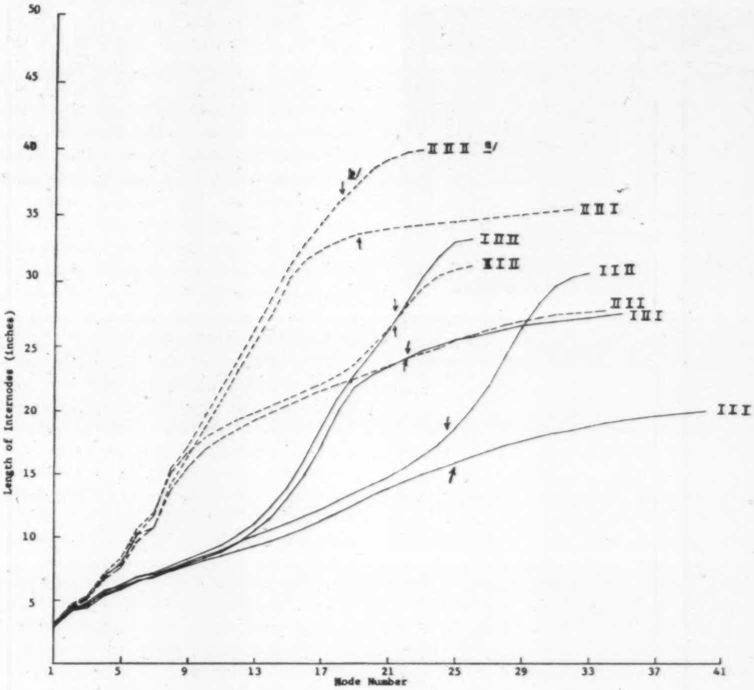

Fig. 2. Growth of plants, expressed as a function of internodal length in inches vs node number. Each curve represents the average internodal lengths of four plants from a control treatment and from seven different experimental treatments. Experimental plants were exposed to 0.6 ppm ethylene for various periods of time. (a) Each II represents one month in control chamber. Each I represents one month in 0.6 ppm ethylene chamber. (b) The arrow refers to the number of nodes per plant at the end of two months.

The gas concentration inside the chamber is readily calculated from the cc/min gas flow and the liters/min air flow. Small temperature fluctuations in the above system are negligible.

Temperature Control

Temperature is automatically maintained to within ±1°F by an electronic control panel. Two duct-type electronic temperature elements are

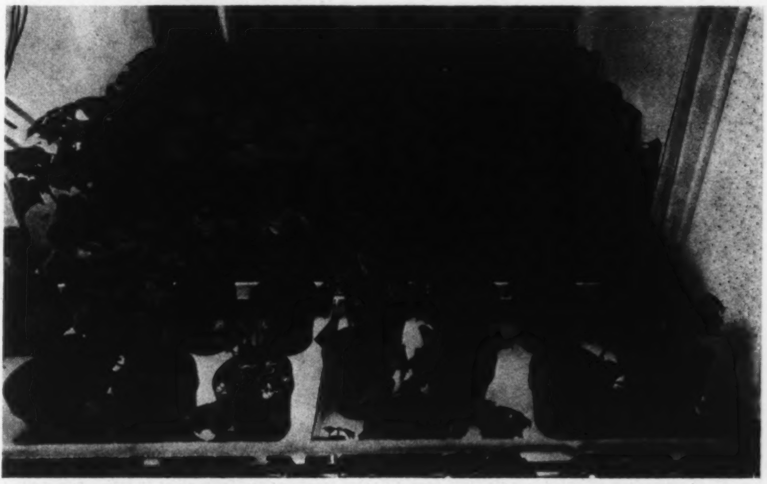

Fig. 3. Cotton plants in chambers after treatment for one month with 0.6 ppm ethylene, control plants in the background.

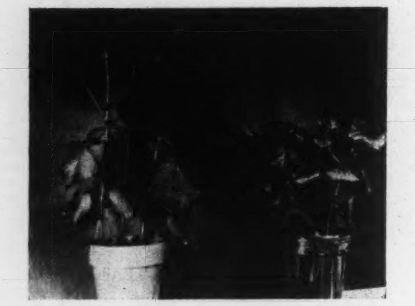

Fig. 4. Comparison of a cotton plant from the control chamber on left, and experimental chamber (0.6 ppm ethylene) after one month of treatment.

mounted in the inlet transition piece. These elements, connected through separate bridge circuits and a single proportioning amplifier, control the temperature sequence controller. One such element with its bridge circuit controls the night temperature, a second the day temperature. The sequence of day and night temperatures is controlled by a time clock in the control panel. The sequence controller is designed to furnish two stages of heating and two stages of cooling.

The switches of the sequence controller, on a call for heating, will activate the relay of stage I heating and then the relay for stage II heating, if more heat is necessary. Stage I heating is accomplished by four 230 v, 1250 w electric resistance heaters installed in the coil box. These heaters are operated on 115 v current to give a total of 1250 w for the four heaters. This prevents excessive heating of the elements, promotes faster cooling, and has proved adequate for winter use under conditions at College Station, Texas. The second stage of heating consists of two separate pairs of the electric heaters. One pair is installed in the coil box and is operated directly by the second stage switch. The second pair is installed just downstream from the blower and prior to the entrance into the inlet transition piece. The latter pair is switched so it can be manually removed from the second stage of heating. These heaters are on 230 v circuits and are used only during the colder months of the year or when high temperatures are required. To date, the first stage of heating has sufficed for all heating requirements.

The switches of the controller, on a call for cooling, activate first one and then a second liquid solenoid valve for two stages of cooling. On the call for the first stage of cooling the switch also activates a relay which starts a one and one-half hp compressor. This sends a refrigerant through the solenoid and into the first set of coils. The second set of coils receives refrigerant on call for second stage. The coils are located in the coil-box as outlined, Fig. 1. The cooling capacity is more than sufficient to reduce outside 100°F air to a low of 50°F at an air flow of 2700 liters per minute.

Temperatures in the experiments reported were maintained at 90° ± 1°F day and 75° ± 1°F night.

Humidity Control

Humidity is automatically maintained to within ±4% RH by an electronic control panel. A duct-type humidity element is mounted in the inlet transition piece. The sensing element consists of a hygroscopic material whose electrical resistance varies with moisture content. This resistance variation is passed through a bridge circuit and proportioning amplifier and controls the humidity sequence controller. A series of six plug-in type base elements is necessary to cover the range of relative humidity from 25 to 95%. Humidity-temperature correction curves show a three percent drop in RH for each 10°F rise in temperature. Therefore, the night RH was from four to six percent above the day values.

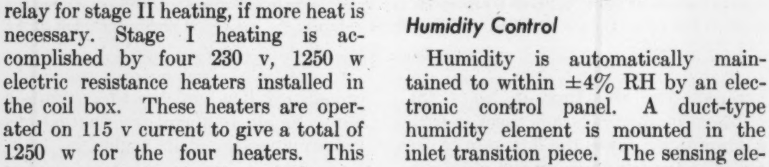

Fig. 6. Comparison of cotton plants from four different treatments. From right to left: two months in control, first month in control plus one month in 0.6 ppm ethylene, first month in 0.6 ppm ethylene plus one month in control, two months in 0.6 ppm ethylene.

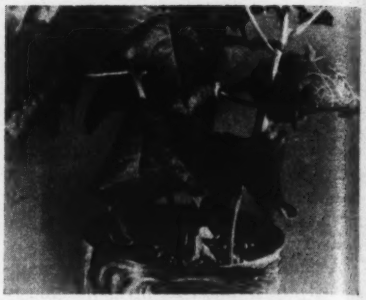

Fig. 5. Close-up of an experimental cotton plant, showing leaf injury, after one month in 0.6 ppm ethylene.

The switches of the sequence controller, on a call for moisture, activate a single stage steam solenoid valve which injects steam into the coil-box downstream from the heating elements. On a call for dehumidification the refrigerant solenoid valves and compressor are activated as for the cooling sequence. Thus dehumidification is accomplished by condensation on the refrigerant coils.

Humidities in the experiments reported were maintained between 65 and 80% RH.

Water from the steam and from condensation of moisture on the cooling coils is drained from the bottom of the coil-box. The drain has a water trap to prevent gas or outside air leakage into the system.

Watering of Plants

Two 3 x 4 ft-3 in. deep galvanized pans were installed in each chamber and covered with three coats of a hard finish white gloss enamel. Each pan is connected by a three inch length of $^3/_8$ inch copper tubing, to the outside of the chamber. This tubing is sealed into the floor and acts as the water inlet and drain. The two pans from each chamber are connected to a single length of $^1/_2$ inch tygon tubing and a water seal maintained to prevent gas leakage. A separate tank, for storing the nutrient solution, is used for each chamber. The nutrient solution is pumped into the chambers every other morning and drained the same afternoon.

Growth of Cotton in 0.6 Ppm Ethylene, Under Controlled Conditions

Preliminary experiments with seedling plants grown for seven to 10 days in 10 ppm ethylene indicated that cotton,

Table I—Milligrams of Soluble, Residue, and Total Nitrogen per Gram Dry Weight from Young Stem, Petiole, and Blade Tissue of Control Plants and Plants in 0.6 Ppm Ethylene at One Month of Age. Results Given Are Averages from the Analyses of Four Separate Plants

Tissue		Values in MgN/Gm Dry Wt Sol. N	 Res. N	 Total N
Young stem	Control	10.42	7.48	17.90
	Experimental	21.68	9.17	30.85
Petiole	Control	13.26	6.96	20.22
	Experimental	16.30	8.63	24.93
Blade	Control	11.34	27.94	39.28
	Experimental	16.72	27.09	43.81
Total	Control	11.67	14.13	25.80
	Experimental	18.23	14.96	33.19

Gossypium hirsutum variety Rex, was very sensitive to ethylene air pollution. Thus it was decided to grow plants from the seedling stage through maturity at an ethylene level which might readily prevail in the vicinity of a polyethylene industrial plant. From field studies[1] and earlier work[2] the level of 0.6 ppm was chosen as a possible mean level of ethylene air pollution.

Methods

Five cotton seeds were planted in each of 60 plastic one-gallon containers filled with a peat-perlite[7] mixture. These were grown in the greenhouse for 12 days, at which time the two most uniform plants from each pot were numbered for future identification and the remaining plants discarded. The plants retained were of uniform height, with healthy cotyledons and one or two true leaves. Thirty containers with two seedling cotton plants per container were placed into each chamber. The chambers were sealed and the following conditions maintained: 90°F ± 1° day temperature with a 67 to 74% RH, 75°F ± 1° night temperature with a 74 to 81% RH, a 12 hour day and a 12 hour night. These conditions were maintained throughout the course of the experiment. Plants were watered every other day with a one-quarter strength Hoaglands solution.[8] The gas concentration in the experimental chamber was maintained at 0.575 ± 0.075 ppm throughout the course of the experiment.

Table II—$Qo_2(N)$ from Discs of Young and Mature Cotton Leaves. A Comparison of Control Plants and Those Treated with 0.6 Ppm Ethylene for One or Two Months. Results Are the Average of Duplicate Treatments

Plant Treatments	$Qo_2(N)$[a] Young Leaves	$Qo_2(N)$[a] Mature Leaves
1 Plants in ethylene free atmosphere for two months	80.7	44.0
2 Plants in 0.6 ppm ethylene for one month then into control for one month	80.0	45.4
3 Plants in control for one month then into 0.6 ppm ethylene for one month	64.2	50.0
4 Plants in 0.6 ppm ethylene for two months	67.8	46.3

[a] $Qo_2(N)$ refers to the microliters of oxygen uptake per milligram of nitrogen per gram dry weight per hour.

Plants were grown for one month and the chambers then opened for an eight hour period. During this time, the following quantitative data were obtained for all plants: plant height; the number of cotyledons, leaves, squares (flower buds), flowers, bolls, laterals, and nodes; the number of plant parts abscissed; and the leaf size in square inches. These data will be discussed later. After the quantitative plant data were obtained one plant from each container was selected for uniformity and retained, the second plant was sacrificed or destroyed.

Plant material for nitrogen analyses was obtained from the plants to be sacrificed. Four uniform plants from the experimental chamber (I) and four from the control chamber (II) were individually separated into blade, petiole and stem tissue. Fresh and dry weights were obtained. The tissue, dried for 48 hours at 55°C, was ground in a Wiley mill and extracted in hot 70% ethanol. Soluble, residue, and total nitrogen were determined for each sample.

The plants which were retained for further treatment were returned to the chambers in the following manner: containers 1 to 15 were returned to the same chamber from which they were removed; containers 16 to 30 from chamber II were placed in chamber I and 16 to 30 from chamber I were placed in chamber II. This was done to determine the recovery rate of treated plants and the effect of the gas on young square-producing (flowering) plants.

These plants were grown for a second month under the initial conditions and the chambers again opened for an eight hour period. The same quantitative plant data were obtained as before for each of the four groups of plants. Then the eight most uniform plants from each group were retained and the remaining seven plants were sacrificed.

Respiration studies were conducted with young and mature leaf tissue from each of the four groups of plants immediately after the plants were removed from the chambers. Duplicate sets of 20, six mm diameter, discs were removed at random from the young and mature leaves of the seven plants to be sacrificed. These discs were placed in 15 cc Warburg flasks for the direct measurement of oxygen uptake.[9] Oxygen uptake was then determined for a one hour period. Due to variations in dry and fresh weights the oxygen uptake is expressed in terms of ul of oxygen per mg N per gm dry weight [$Qo_2(N)$]. Fresh weight, dry weight, and total nitrogen were determined for each group of leaf discs.

The eight plants retained from each of the four test groups were returned to the chambers in the following manner. (The designation I stands for one month in the experimental chamber and II for one month in the control chamber.) Plants in I-I were divided so that four remained in the experimental chamber (I) and four were placed in the control chamber (II). Plants in I-II, II-II, and II-I were divided in the same manner to give the following eight final treatments: I-I-I, I-II-I, I-II-II, I-I-II, II-II-I, II-I-II, II-I-I, and II-II-II. These treatments also lasted for one month under the initial conditions. At the end of these treatments the plants were removed from the chambers and the same quantitative plant data were obtained as before for each of the eight

Table III—Milligrams of Nitrogen per Gram Dry Weight from Leaf Disc Tissue from Young and Mature Cotton Leaves. A Comparison of Control Plants and Those Treated with 0.6 Ppm Ethylene for Various Periods of Time. Results Are the Average of Duplicate Treatments

Plant Treatments	MgN/Gm Dry Weight Young Leaves	 Mature Leaves
1 Plants in ethylene free atmosphere for two months	43.84	32.31
2 Plants in 0.6 ppm ethylene for one month then into control for one month	47.59	31.46
3 Plants in control for one month then into 0.6 ppm ethylene for one month	49.98	31.38
4 Plants in 0.6 ppm ethylene for two months	51.86	33.77

Table IV—Percent Dry Weight of Leaf Disc Tissue from Young and Mature Cotton Leaves. A Comparison of Control Plants and Those Treated with 0.6 Ppm Ethylene for Various Periods of Time

Plant Treatments	Dry Weight of Respiratory Tissue, % Young Leaves	Dry Weight of Respiratory Tissue, % Mature Leaves
1 Plants in ethylene free atmosphere for two months	21.5	16.4
2 Plants in 0.6 ppm ethylene for one month then into control for one month	19.9	11.6
3 Plants in control for one month then into 0.6 ppm ethylene for one month	15.0	17.4
4 Plants in 0.6 ppm ethylene for two months	16.0	13.8

groups of plants. The plants were then discarded.

Results

Nitrogen analyses of month old tissue are shown in Table I. Significant increases in soluble nitrogen are shown in all tissues treated with ethylene but with no resultant decrease in residue nitrogen. Actual residue nitrogen of stems and petioles is almost significantly higher in the ethylene treated plants while blade tissue shows essentially the same residue nitrogen under control and experimental conditions. The significant increase in total nitrogen does not correspond to results generally found with reactants causing plant injury.

Respiration studies are shown in Table II. The $Qo_2(N)$ is significantly lower in the young leaves initiated and grown in ethylene than in the young control leaves. These resuts are contrary to much earlier work with higher ethylene concentrations over a short treatment period. Differences in the mature leaf tissue are not significant but tend to indicate a higher rate of respiration in the ethylene treated tissues.

Nitrogen analyses (Table III) correspond very closely with those obtained after one month. When mature and young leaf analyses are combined for plants in the control for two months and plants in ethylene for two months and the total nitrogen of the control plants is expressed as a percent of total nitrogen in the ethylene treated plants the following results are obtained: after one month the leaf blades from control plants contain 89.6% of the total nitrogen found in ethylene treated blades and after two months this same percentage is 88.9. Thus there is a fairly stable nitrogen balance maintained in the ethylene treated tissues.

Table V—Comparison of Plant Height in Four Control Plants and Four Plants from Each of Seven Experimental Treatments. The Experimental Plants Were Exposed to 0.6 Ppm Ethylene for Various Periods of Time

Treatment	One Month	Two Months	Three Months
II II II[a]	19.9	34.38	42.75
II II I			37.75
II I II		24.83	34.84
II I I			32.00
I II II	11.5	24.83	37.00
I II I			31.75
I I II		19.25	34.60
I I I			25.75

[a] Each II represents one month in control chamber. Each I represents one month in 0.6 ppm ethylene chamber.

Visual observations indicated that ethylene treated leaf blades are thicker than control leaf blades. Fresh weights of the leaf discs confirmed this observation but dry weights were only slightly and not significantly different. This high water content of ethylene tissues is of possible significance and the results are shown in Table IV. All leaves initiated in ethylene show a significant reduction in percent dry weight and thus an increase in total tissue water. Reason for this tissue hydration is not readily apparent.

Quantitative plant growth data for height, leaf number, number of floral structures, number of laterals, number of nodes, leaf size, and number of leaf abscissions are shown in Tables V–XI. The results given in these tables include only the 32 plants which were grown for the entire growth period. Thus each figure for one month is the average of 16 plants, for two months is the average of eight plants, and for three months is the average of four plants.

The expression of each factor is associated with plant age, interval of treatment, and length of treatment.

Table VI—Comparison of the Number of Leaves from Four Control Plants and Four Plants from Each of Seven Experimental Treatments. The Experimental Plants Were Exposed to 0.6 Ppm Ethylene for Various Periods of Time

Treatment	One Month	Two Months	Three Months
II II II[a]	16.63	34.25	40.50
II II I			89.25
II I II		61.50	67.25
II I I			110.00
I II II	17.00	33.88	51.75
I II I			80.25
I I II		35.75	54.25
I I I			81.25

[a] Each II represents one month in control chamber. Each I represents one month in 0.6 ppm ethylene chamber.

The data for the first two months are rather easy to interpret but, for certain factors, the third month is more difficult. The natural maturation of the control plants plays a major role in some of the third month results. In addition, the plants in the control chamber were subjected to water stress one week after the beginning of the third month. This resulted in increased abscission of squares and leaves and affected these tabular results as well as the results for leaf size.

Figure 2 is a visual expression of plant growth expressed as a function of internodal length in inches versus node number. The graph shows clearly the two treatments of the first month, the four of the second month, and the eight of the third month. The arrows indicate the number of nodes formed at the beginning of the third month of treatment. The increase in growth, at these points, of the control over the experimental plants is an indication of the inhibitory effect of ethylene on internode elongation.

A visual description of plant injury is demonstrated by Figs. 3–6. Figure 3 shows plants growing in the two chambers at the end of the first month of growth. This picture depicts the uniform growth obtainable in these chambers and illustrates the general injury symptoms noted on young developing cotton plants. Figure 4 shows a closer comparison of a control and an experimental plant at the end of one month. Figure 5 is a closeup showing injury symptoms on the treated plant. Figure 6 shows a plant from each of the four experimental treatments taken at the end of two months. The two middle plants readily show the effects of the month in the gas as opposed to the month under control conditions.

Seedlings started in 0.6 ppm ethylene

Table VII—Comparison of the Number of Squares, Flowers, and Fruits from Four Control Plants and Four Plants from Each of Seven Experimental Treatments. The Experimental Plants Were Exposed to 0.6 Ppm Ethylene for Various Periods of Time

Treatment	One Month	Two Months	Three Months
II II II[a]	1.13	17.50	13.00
II II I			2.75[b]
II I II		0.00	7.25
II I I			3.75[b]
I II II	0.00	3.88	7.75
I II I			1.25[b]
I I II		0.00	9.50
I I I			1.00[b]

[a] Each II represents one month in control chamber. Each I represents one month in 0.6 ppm ethylene chamber.

[b] Minute squares which will shortly abscise.

Table VIII—Comparison of the Number of Laterals from Four Control Plants and Four Plants from Each of Seven Experimental Treatments. The Experimental Plants Were Exposed to 0.6 Ppm Ethylene for Various Periods of Time

Treatment	One Month	Two Months	Three Months
II II II[a]	7.4	15.25	14.50
II II I			43.00
II I II		16.50	21.00
II I I			42.25
I II II	4.9	11.13	16.00
I II I			43.50
I I II		13.75	20.50
I I I			31.50

[a] Each II represents one month in control chamber. Each I represents one month in 0.6 ppm ethylene chamber.

show an extremely slow but definite response to the gas. Initially there is a tendency for leaf epinasty, however this effect has never been pronounced in cotton, as shown in other plants. After a week in the ethylene atmosphere, it is impossible to determine the epinastic response. At this time there is a definite decrease in plant height, a beginning indication that node formation in ethylene is more rapid and thus a definite effect on internodal length. Leaf size is notably reduced and the leaf has started to develop a typical crinkled surface with a coarse or granular surface texture. This effect increases in severity with time. Leaf chlorosis has never been pronounced with leaves initiated in ethylene. Some cotyledons developed partial chlorosis and both chlorotic and normal appearing cotyledons began abscissing after 16 to 20 days in the ethylene. All the cotyledons abscissed before the end of the first month. Stipules appeared to be especially sensitive with only the terminal three to four nodes bearing live stipules. No indication of squaring was noted during the first month in ethylene.

Table IX—Comparison of the Number of Nodes[a] from Four Control Plants and Four Plants from Each of Seven Experimental Treatments. The Experimental Plants Were Exposed to 0.6 Ppm Ethylene for Various Periods of Time

Treatment	Two Months	Three Months
II II II[b]	18.50	23.00
II II I		32.00
II I II	21.38	25.75
II I I		33.50
I II II	21.75	26.75
I II I		34.50
I I II	25.13	32.00
I I I		39.25

[a] Node number was not obtained at end of one month.

[b] Each II represents one month in control chamber. Each I represents one month in 0.6 ppm ethylene chamber.

Plants grown for one month in the control and then transferred to the gas treatment showed terminal effects as noted previously. Internodal elongation seemed to be slowed at once. Young leaf malformations were typical. Mature leaves developed slight to extensive chlorosis and abscissed within seven to 10 days. Young almost mature leaves stopped enlarging, developed slight malformations, but showed no chlorosis and did not abscise. Squares abscissed and only slight evidence of new square formation was noted. At the end of two months some evidence of squaring was noted but all squares were necrotic. This was true of both groups of plants in ethylene after two months.

Plants grown in ethylene for one month and transferred to the control chamber showed immediate stimulation of terminal growth. Older tissues showed no recovery, young tissue showed partial recovery, and newly forming tissue showed no injury symptoms whatever. Square formation was delayed for two weeks but this was probably due to death of floral initials and the two week interval was the time required to lay down and develop new initials.

During the initial two months of growth little variation in leaf number or lateral development was noted between ethylene-treated and control plants. However during the third month, all treatments in ethylene showed a tremendous stimulation of both leaf and lateral number. This was especially noted by the development of two definite laterals per node and of laterals on laterals. This extensive growth produced a heavily foliated shrub-like appearance in the experimental plants. Over-all effects during the third month were similar to these noted for the first two months. Extensive square development was demonstrated by the production of many minute necrotic squares with only a few small squares which were green and showed no tendency to abscise.

Table X—Comparison of Leaf Blade Size[b] from Four Control Plants and Four Plants from Each of Seven Experimental Treatments. The Experimental Plants Were Exposed to 0.6 Ppm Ethylene for Various Periods of Time

Treatment	One Month	Two Months	Three Months
II II II[a]	45.92	50.17	33.19
II II I			19.84
II I II		20.07	21.87
II I I			14.06
I II II	17.64	42.87	39.28
I II I			7.27
I I II		22.55	32.95
I I I			11.41

[a] Each II represents one month in control chamber. Each I represents one month in 0.6 ppm ethylene chamber.

[b] Leaf blade size obtained by multiplying length x width x $^3/_4$. The $^3/_4$ was used in all determinations as a constant to correct for irregularities of blade. In all cases the largest leaf on the plant was used for measuring blade size.

Discussion

The results of field observations are rather difficult to interpret in light of the above experimental results. Two major field symptoms[1] were the extensive development of laterals with a resultant prostrate growth habit and the abscission of all squares. Internodal lengths, and node numbers were not compared but injury symptoms so characteristic of chamber-grown plants were entirely lacking in field grown plants. This suggests that field concentrations are far below those actually used under chamber conditions and although this conclusion may be valid, it does not fit with data obtained in the field.

A second interpretation is perhaps as valid and does fit field data on atmospheric concentrations. It is a well accepted thesis that atmospheric conditions will have a major effect on the concentration of air pollutants over any given area. The other factor controlling pollutant concentration will be the amount released from the industrial operations at any given time. We know that floral structures in cotton are extremely sensitive to ethylene gas as are the young developing stem tips and thus potentially the lateral buds. Floral sensitivity results in death while lateral vegetative bud sensitivity results in a growth stimulation. Present experimental results show that typical injury symptoms are in essence a

Table XI—Comparison of the Number of Leaf Abscissions[a] from Four Control Plants and Four Plants from Each of Seven Experimental Treatments. The Experimental Plants Were Exposed to 0.6 Ppm Ethylene for Various Periods of Time

Treatment	One Month	Two Months	Three Months
II II II[b]	0.44	4.75	10.25
II II I			29.25
II I II		7.75	14.75
II I I			26.25
I II II	2.00	5.50	14.25
I II I			28.50
I I II		9.25	17.50
I I I			31.75

[a] Leaf abscissions include cotyledons.

[b] Each II represents one month in control chamber. Each I represents one month in 0.6 ppm ethylene chamber

growth response and thus relatively slow, that plants removed from ethylene show no after effects and that once floral initials are killed new ones will not develop for several weeks. Preliminary experiments using 10 ppm ethylene with cotton seedlings produced cotyledon and leaf abscission within 60 hours with no leaf abscission if plants were removed before the abscission process was initiated. Thus a second interpretation of field results would suggest that periodically the weather conditions and the amount of gas emanating from the industrial operation are optimal for the maintaining of high field levels of ethylene over a relatively long period of time (eight to 30 hours). These maintained levels could be sufficiently high over a specified period of time to initiate the death of floral initials and to stimulate the development of lateral buds. The level would be too low over the maintained period for the consumation of leaf abscission or development of marked leaf malformations and since no after effects are noted, the field manifestations would logically be square abscission and lateral development. Thus during the major portion of the growing season the air levels may be negligible but the end result is still a total loss or reduced cotton yield in spite of the healthy plants.

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POLICY ON SECTIONAL ORGANIZATION DEFINED

The following is a Statement of Policy on Sectional Organization in APCA.

1 The name of the Section shall be the "——————— Section of the Air Pollution Control Association."

2 Not fewer than ten active members of APCA in good standing (or eligible applicants for membership in APCA) may apply as an organizational committee for authorization to form a section.

3 A sectional organization of APCA can be recognized only if approved by the Board of Directors of the Association.

4 The Board of Directors shall establish the geographical boundaries of the area in which each section shall be active. In setting such boundaries, the Board shall consider available transportation facilities for commuting, having the prerogative of restricting boundaries where found necessary to do so, and changing a boundary at a later date to prevent sections in adjacent areas from overlapping.

5 A member of a sectional organization shall be required to maintain an active membership in APCA in good standing.

6 A member of APCA having his residence or place of business within the bounds of a sectional organization may become a member of that section to participate locally in its activities. A member of APCA may participate in the activities of only one sectional organization.

7 As in APCA memberships, there is a broad area of interest (educational institutions, research institutes and agencies, industrial establishments, manufacturers of air pollution control equipment, civic organizations and citizen groups, governmental agencies including control officials, representatives of state and county governments, and members of federal agencies such as the Bureau of Mines, Public Health Service, etc.). So, in the local sections will there be a broad area of interest. Therefore, it shall be the policy of sectional groups to balance the interests of their officers to represent the area of interest of their particular group.

8 A sectional organization shall be considered active only if:

(*a*) Its membership includes a minimum of 25 active members.

(*b*) It holds at least one meeting during a calendar year.

(*c*) It functions and operates in compliance with the By-Laws of APCA.

9 A sectional organization shall submit an annual report each year to the Executive Secretary of APCA for transmittal to the Board of Directors which shall include:

(*a*) Number of active members, showing any increase or decrease of membership for the year.

(*b*) Affairs of the section.

(*c*) A brief resume of business transactions.

(*d*) A listing of public meetings (Technical Meetings, Seminars, etc.).

(*e*) A financial statement.

10 A sectional organization or its members shall, *only* with the specific approval of the Board of Directors of the Air Pollution Control Association in each instance of occasion:

(*a*) Hold technical meetings under the APCA name or sectional organization auspices.

(*b*) Publish papers under the APCA name or section organization sponsorship.

(*c*) Speak authoritatively for the Association or the sectional organization.

Pollen SAMPLING *and* DISPERSION STUDIES *at Brookhaven National Laboratory*[*,†]

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Since its establishment in 1947, the Meteorology Group at Brookhaven National Laboratory has been concerned with the diffusion and dispersion of gases and small particulates in the atmosphere. Most of the earlier field experiments involved diffusion of oil-fog smoke over intermediate distances. More recently, programs have been initiated for the study of diffusion over longer distances and of dispersion and deposition of larger particles over relatively short ranges. In addition, a co-operative project was established in 1955 by the Laboratory and the State Botanist's Office of the New York State Museum and Science Service for the study of airborne pollen. This project was under the over-all direction of Dr. Ogden, and was participated in by the Laboratory Biology and Health Physics Departments as well as the Meteorology Group.

The objectives of the original project were studies of the variation of natural pollen concentration with height and its relation to meteorological conditions. It soon became obvious, however, that these aims could not be realized with the pollen samplers available, and a program of sampler evaluation and development was begun which has continued to the present. In 1958 and 1959, experiments were conducted to determine the feasibility of tagging ragweed (*Ambrosia*) pollen in the growing plant with a substance that could be readily identified in the collected pollen in order to study dispersion from a known source. In 1959, preliminary studies were made of the dispersion of untagged ragweed pollen from a cultivated plot, and in 1960 full-scale dispersion tests were started. Current plans envision a continuation of the sampler testing and development program, an expansion of the dispersion studies, and an extension of the experiments to several other types of airborne pollens and to other locations.

Evaluation of Current Pollen Sampling Devices

In 1946, the Pollen Survey Committee of the Research Council of the American Academy of Allergy recommended the Durham sampler as the standard instrument for sampling airborne pollen,[1] and this device has been generally used ever since. It consists of a standard microscope slide coated with a sticky substance on the exposed side and mounted in a rectangular holder midway between two nine-inch diameter disks. Although originally believed to collect by gravity settling, it is now generally agreed that turbulent impaction is the primary mechanism involved in deposition on the slide.

In 1955, two samplers of this type were mounted close together at eight levels from nine to 410 feet on the Brookhaven Meteorology tower and operated throughout the ragweed pollen season. At each level, one sampler was installed with the long axis of the slide in a north-south position, and the other east-west. In addition, volumetric samples were taken at several levels with Millipore filters. Inspection of the results revealed that the north-south slides took 16% more pollen than the east-west slides. This was found to be correlated with a preponderance of north and south winds.

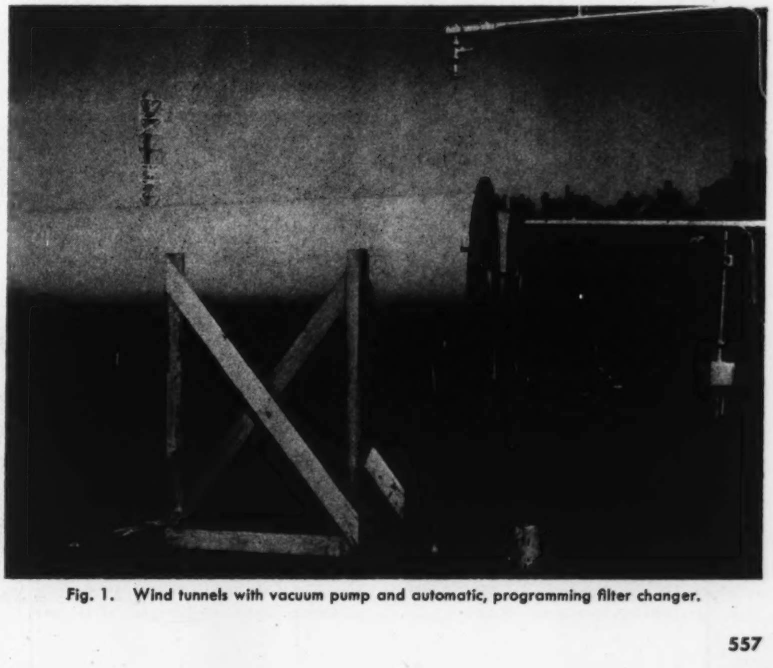

Fig. 1. Wind tunnels with vacuum pump and automatic, programming filter changer.

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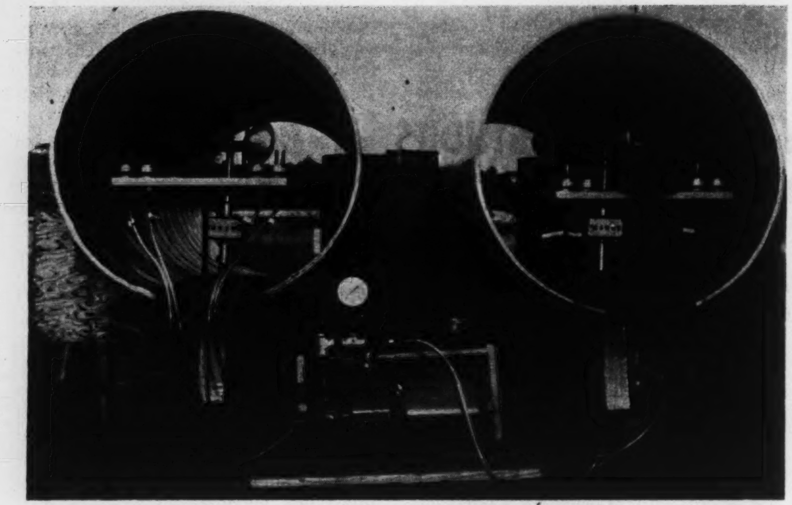

Fig. 2. Anemometer and sampling devices in wind tunnel.

The slide counts also indicated an average concentration at the top of the tower twice that at the bottom, while the volumetric counts showed an opposite trend. These results led to a thorough investigation both in the field and in a wind tunnel of the reasons for these results. The findings were recently published in the *Journal of Allergy*[2] and will not be repeated in detail here. In brief, however, it was found that the catch on the slide was related to the amount of air passing over the slide as well as to the actual concentration. This was demonstrated in two wind tunnels placed side by side in the field, but operated at different air speeds (Figs. 1 and 2). It was also shown that at a given air speed, a horizontal slide oriented with its long axis parallel to the air stream would collect more pollen than one oriented across the flow. These results were obtained by mounting two Durham samplers on a wind vane which kept one slide always parallel with the wind and the other normal to it (Fig. 3). Wind tunnel study of the flow patterns across the slides showed that the blunt leading edges of the slide and holder gave rise to aerodynamic effects which differed in the two orientations. Rather similar results had been obtained earlier by Gregory and Stedman[3] in England.

The filter samplers were found to suffer from other defects. Since they could not be used isokinetically, their efficiency decreased rapidly as the wind speed increased. This flaw was found to be present in several other types of volumetric samplers and is probably characteristic, in some degree, of all.

Development of New Pollen Sampling Devices

During the next several years, several new or improved types of pollen samplers were developed. Low cost, simplicity of design and operation, accuracy of sampling, and ease in reading the sample are important considerations for a field sampler, and attempts were made to adhere to these criteria in all instruments designed. Unfortunately, no simple instrument has been devised that will sample particles in the pollen size range with high efficiency under all conditions commonly encountered in the free air. However, the instruments described are regarded as improvements over those currently used.

Only one device employing the principle of deposition on a horizontal surface was designed. This is a circular streamlined holder for square glass slides mounted in a standard Durham shelter (Fig. 4). Wind tunnel tests indicate that a smooth flow pattern exists over the surface throughout the normal range of wind speeds and because of its shape, no directional effects are present. In common with the rectangular slide and holder, however, its sampling efficiency varies with wind speed and turbulence. An attempt is being made to define this variation empirically, but even if successful, satisfactory use of the sampler would necessitate concurrent use of an anemometer and possibly some measure of turbulence.

A second family of instruments that appears to be more useful is based on the principle of impaction on the side of a vertical cylinder, a method previously tested by Gregory,[4] and used in the pin flag sampler by experimenters at the University of Michigan.[5] The efficiency of these samplers varies directly with air speed, particle size, and particle density, and inversely with cylinder diameter. Equations have been developed by Gregory and others which define the efficiency in terms of these parameters. Therefore, in sampling a known type of particle with a sampler of fixed diameter, a curve of efficiency versus wind speed is easily drawn and may be used to correct the sample to true concentration if the

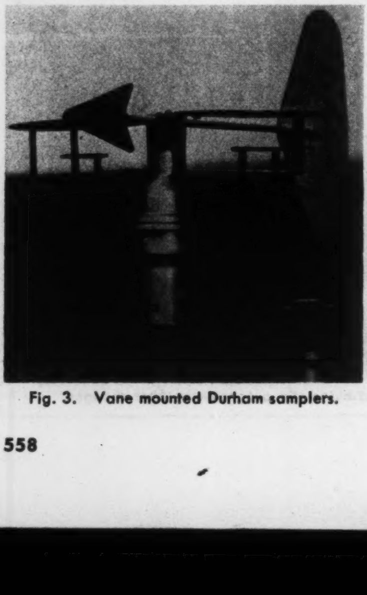

Fig. 3. Vane mounted Durham samplers.

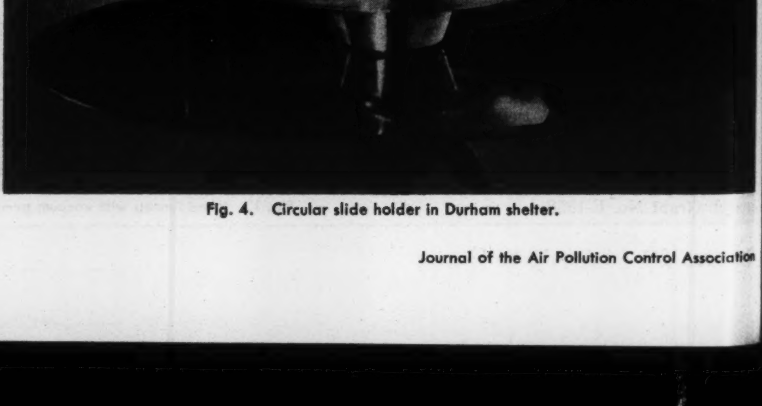

Fig. 4. Circular slide holder in Durham shelter.

wind speed is known. In order to avoid the necessity of reading the whole circumference of the cylinder, it is commonly fixed to a vane which keeps one side facing the wind at all times. The size of the cylinder must be small enough to have reasonable efficiency at the lowest wind speeds likely to be enountered and large enough to avoid overloading in heavy concentrations over the longest sampling period desired. It is also important that the sampling surface be easy to read under the microscope.

Figure 5 illustrates a test device having two types of vane-mounted cylindrical sampling surfaces. The larger is a rectangular slide of thin transparent plastic held in a curved position on the leading face of a $1^{7}/_{8}$ inch diameter aluminum cylinder. The slide regains its flat shape when removed from the holder and may be handled and examined like a glass slide, but the cylinder size is too large for acceptable efficiency at low wind speeds.

The second device mounted in duplicate is a $^{3}/_{8}$ inch diameter lucite cylinder with a $^{1}/_{16}$ inch flat machined on the forward side as the collecting surface. These rods had acceptable efficiency, but were difficult to handle and store and quite troublesome to examine under the microscope.

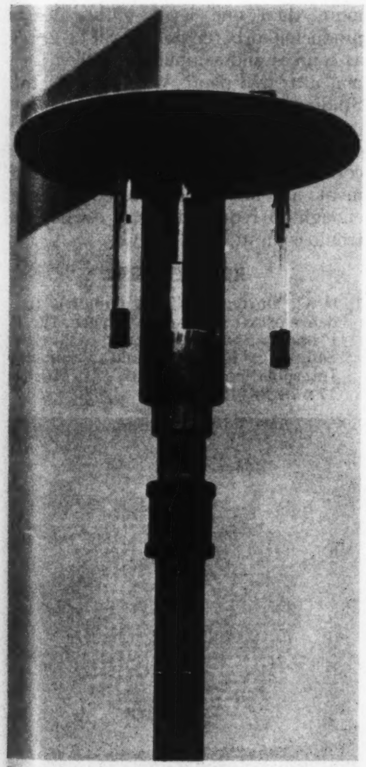

Fig. 5. Plastic slide and lucite rod cylinder sampler.

A third vane-mounted impaction sampler (Fig. 6) proved more satisfactory and was used in quantity during the 1960 sampling season. It consists of a glass microscope slide mounted vertically between two aluminum bars on the front of a small vane. The leading edge of the slide serves as the sampling surface. The bars are machined to present a $^{1}/_{4}$ inch diameter cylindrical surface to the wind and are made $1^{1}/_{2}$ inches longer than the slide to avoid turbulent effects around the ends of the sampling area. The theoretical efficiency of this sampler for ragweed pollen varies from about 10% at one mph to about 80% at 25 mph. Therefore, an anemometer must be used in conjunction with it. This sampler is inexpensive, easy to use, and compared to a horizontal sampling surface, quite efficient. It may be exposed for 24 hours without overloading even under heavy pollen concentrations. The slide edge has proved easy to read under a microscope, necessitating only a single sweep at 100 diameters and as many as 24,000 pollen grains have been recorded from a single sample. The major defect of this and all other impaction devices is its varying efficiency with wind speed and the necessity of an associated wind speed measurement. A somewhat modified and improved design is under construction for the coming season.

A group of powered impaction instruments has been developed by modification of the rotorod invented by the Stanford University Aerosol Laboratory.[6] In 1959, rotorods were used singly and grouped in sequential units as in Fig. 7. The sampling rods rotate at about 2500 rpm and have a linear speed of about 23 mph. They are essentially independent of wind speed and direction and sample about 120 liters/min. This device has an efficiency of near 100% for 20μ particles, is inexpensive and easy to operate, but overloads too quickly to be used for more than two or three hours at a time. In addition, the metal rods are difficult to read under a microscope.

In order to obtain 24 hour samples with the rotorod, two procedures are possible. A group may be operated sequentially or a single unit may be used intermittently to give a representative sample. In both cases, however, one important factor must be considered: The rotorod is a highly-efficient sampler even when not rotating if it happens to be stopped with a collecting surface facing the wind. In the sequential unit shown in Fig. 7, each rotorod operated for two hours and was idle for 22. On a number of occasions, large discrepancies were noted between the two uprights of the same collector, so tests were made proving the ability of the rods to collect large amounts while idle. It was concluded, therefore, that both sequential units and intermittently operated units must be covered when not in operation.

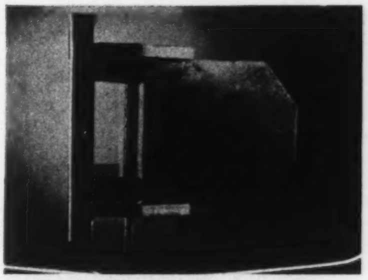

Fig. 6. Slide-edge cylinder sampler.

Because of the difficulty of covering the type of sequential unit shown in Fig. 7, the Belt Rotorod shown in Fig. 8 was built. Each rotorod unit is operated for two hours by the drive motor, then revolved into the box and replaced by the next. This unit had certain mechanical difficulties, but an improved model is now under construction and is expected to operate satisfactorily.

Where a representative sample taken at periodic intervals is adequate, the intermittent rotorod unit shown in Fig. 9 may be used. The shield rises automatically to cover the rotorods when idle and descends when they begin rotation. A number of these samplers were used during the 1960 season and were usually timed to sample for a total of two hours in 24 using such cycles as one minute of every 12, $2^{1}/_{2}$ of every 30, or five minutes of each hour. Models were built for both 110 v AC and for 12 v DC power. The cost of these units is modest and their operation simple and reliable.

Because of the difficulty of counting pollen on the metal rods, narrow strips of transparent tape were fastened to the leading faces and greased to serve as the collecting surfaces. After exposure, the tapes were removed and laid flat on a microscope slide for counting. This procedure is not wholly satisfactory, however, and the rotoslide, a new instrument in which the edge of a microscope slide replaces the metal rods, is

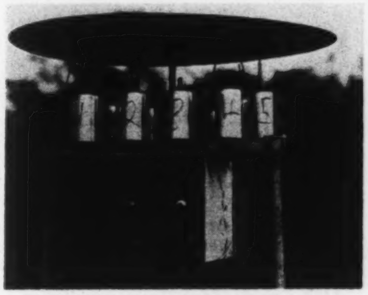

Fig. 7. Sequential rotorod unit.

Fig. 8. Belt driven sequential rotorod unit.

now under test and is expected to alleviate the handling and counting difficulties of the rotorods.

Tagging of Ragweed Pollen

In 1958 and 1959, extensive tests were made, both in the greenhouse and in the field, of the feasibility of tagging ragweed pollen with an identifiable substance.[7] A number of vital dyes, both fluorescent and nonfluorescent in a wide range of concentrations, were introduced into the plants by a variety of methods including direct injection and hydroponic culture. In no case did a recognizable amount of dye reach the pollen without injuring the plant so badly that natural pollination was inhibited.

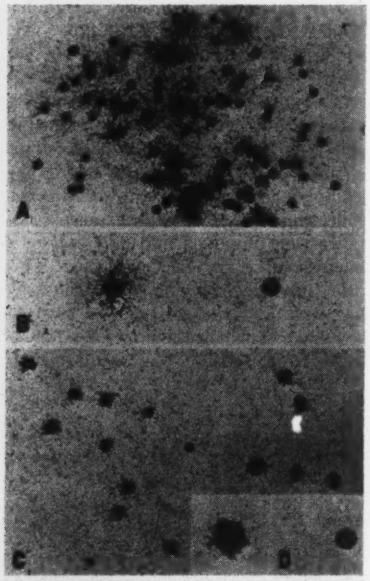

Fig. 10. Autoradiographs of ragweed pollen. A. Tagged and untagged grains from plant injected with P^{32}. ×200. B. Tagged and untagged grains from plant injected with P^{32}. ×500. C. Tagged and untagged grains from plant injected with S^{35}. ×200. D. Tagged and untagged grains from plant injected with S^{35}. ×500.

Other tests were made with the radioisotopes P^{32} and S^{35} introduced into the plants by various methods. It was found that these substances entered all parts of the plant including the pollen without interference with the natural pollination process, but that the amount of radiation per pollen grain varied with location on the plant and with time. Amounts used were limited to one millicurie per plant, and this was generally too small to tag all pollen grains on large plants. The activity in pollen samples collected directly from the plant could be measured with a Geiger counter and binary scaler, when the number of grains per sample was 5000 and over. Small numbers of tagged grains sampled from the air could be readily recognized and counted by use of autoradiographs (Fig. 10), but this method is not well adapted to mass sampling.

A third and more successful method of providing a known source of ragweed pollen is treatment of the plants to pollinate before the normal season by artificially shortening the day length. This method has been used in dispersion studies at the University of Michigan[8] beginning in 1956 and at Brookhaven in 1960.

Ragweed Dispersion Studies

In 1959, preliminary studies of dispersion from an acre plot of cultivated ragweed were made. In 1960, a field of pre-season ragweed (Fig. 11) 60 feet in diameter was surrounded by 72 vane-type samplers mounted five feet above the ground in four concentric circles located 30, 60, 90, and 120 feet from the center of the field. Sampling was continued for 12 days with samples changed daily. An annular ring 180 feet in outer diameter of untreated ragweed plants was grown concurrently around the inner plot and came into pollination after the early sampling had ended. The same samplers were spaced at distances of 90, 120, 180, and 300 feet from the center of the field and operated for 32 days. Associated meteorological measurements were taken during both sampling seasons. Although many of the samples taken have not yet been counted and analyzed, enough data have been studied to show that a regular dispersion pattern exists (Fig. 12). Concentration (Fig. 13) shows a nearly logarithmic decrease with distance both down the center line of the plume and in the average of all directions. Detailed studies of these data are expected to have important application in air pollution problems, since the pollen field, like a city or an industrial complex, represents an area source having an output varying with time and meteorological conditions.

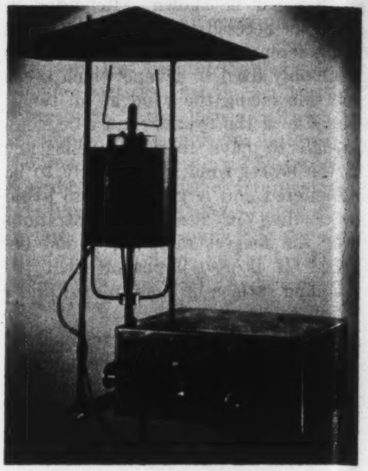

Fig. 9. Rotorod unit for intermittent sampling.

Future Work

With funds provided by an extension of the research grant, present plans call for a four-year continuation of these studies. Evaluation and development of samplers will be continued. Dispersion tests will be expanded through use of two fields and by sampling at more than one level. Other plants producing airborne pollen will be grown as sources and sampling of pollen from noncultivated plants will be conducted. Studies will be made of the dispersion of pollen through forests as well as over open terrain. All data taken will be correlated with meteorological measurements and are expected to be extensive enough to require the use of an electronic computer for analysis.

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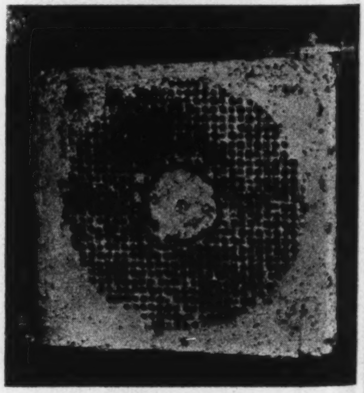

Fig. 11. 1960 cultivated ragweed field.

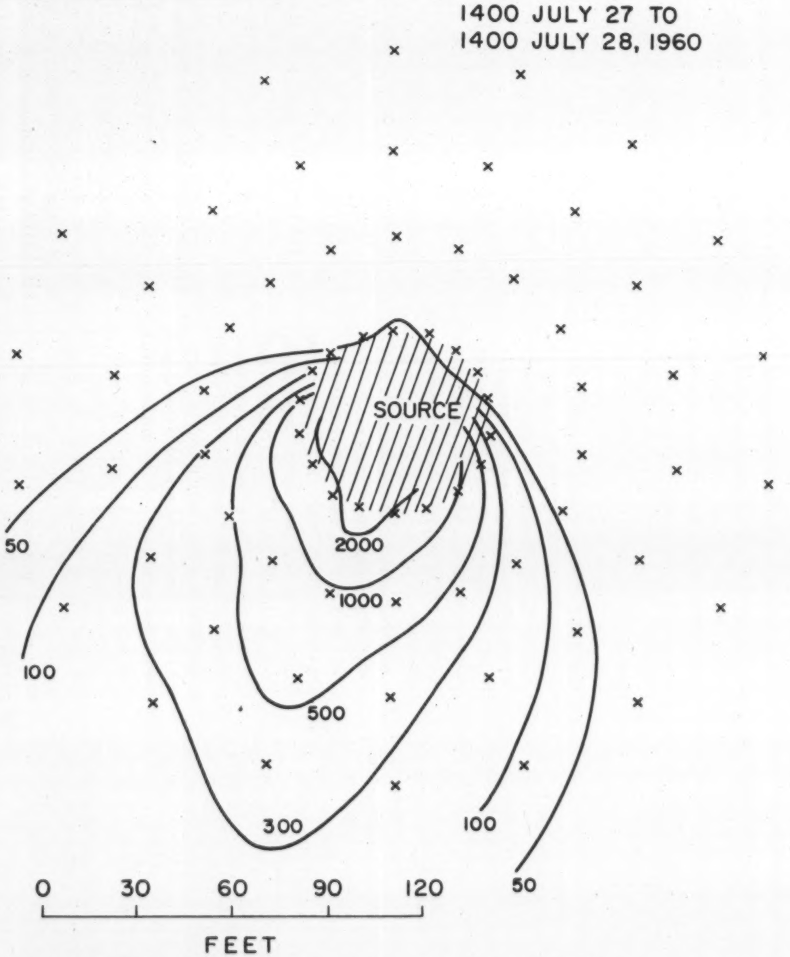

Fig. 12. Typical dispersion pattern from cultivated ragweed plants. Sampler locations are marked by X. Isolines are in pollen grains/m³.

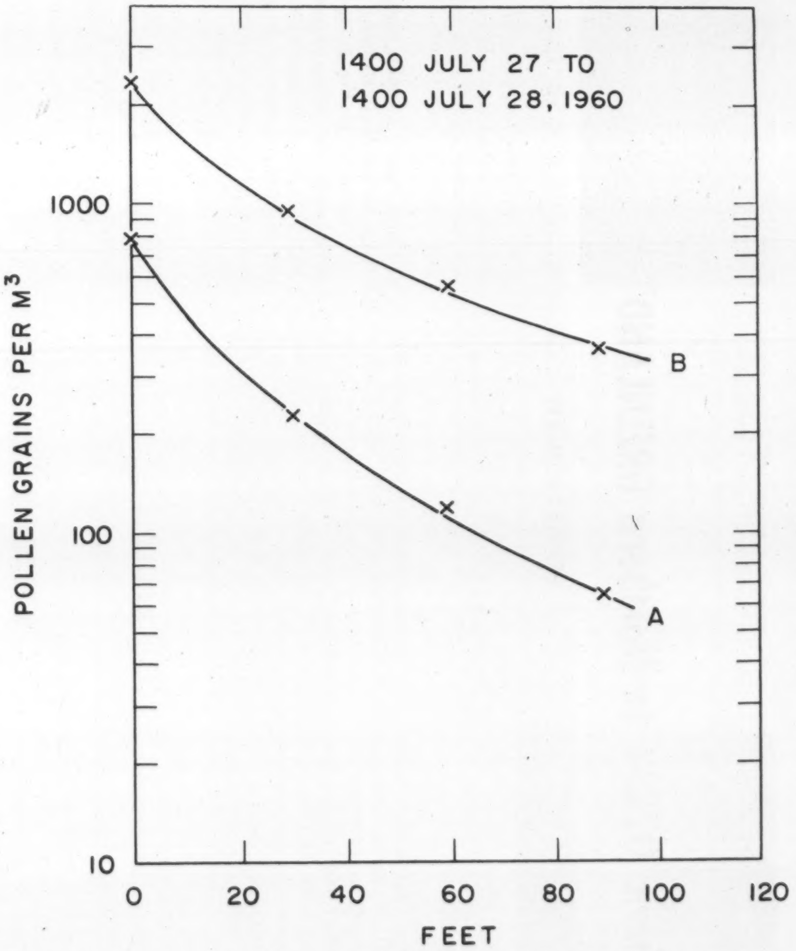

Fig. 13. Variation of concentration of ragweed pollen with distance from edge of ragweed plot. A. Average of all directions. B. Downwind direction.

(*Continued on p. 584*)

Atmospheric OZONE in Northern GREENLAND*

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This investigation was undertaken by the U. S. Army Ordnance Corps in an attempt to determine the reason for excessive cracking of tires and other rubber items in storage at Camp Tuto, located in Northern Greenland approximately 940 miles from the North Pole. Atmospheric ozone concentrations were measured by two chemical methods and meteorological and other related data were obtained, in an attempt to determine the environmental factors responsible.

Since ozone is of some importance in photochemical smog reactions, this paper is being prepared to present information relative to the mechanism by which ozone occurs as a natural constituent of the atmosphere.

To illustrate the type of observations which led to this investigation, Figs. 1, 2, and 3 show tires found in the storage area of the U. S. Army Polar Research and Development Center, Camp Tuto, Greenland. On the other hand, Fig. 4 shows a tire which was seven years old and had been in almost daily use in the vicinity of San Antonio, Texas. The cracking of the sidewall of this tire is characteristic of that usually found in the temperature zone. By comparison, tires and other items found in the storage area at Camp Tuto showed much more severe cracking. Unfortunately it was not possible to determine the previous history of most of the items prior to their arrival at Camp Tuto, but none of these items could have been in storage at that location for periods longer than two years. The prevalence of severe cracking would indicate that at least part of the damage occurred in Greenland. In addition, Fig. 3 shows damage which obviously occurred at Camp Tuto. This tire was half flat and at the point where the sidewall was deformed, cracks had formed which extended to the fabric beneath, while the rest of the sidewall showed no deterioration.

Meteorological Conditions

Ozone is a normal trace constituent of the atmosphere, formed by the action of ultraviolet radiation. Many measurements of normal atmospheric ozone have been made, both at ground level and aloft, including a few in Greenland and other Arctic locations. Extensive reviews and bibliographies are available[1–5] so that this information need not be reviewed in detail here. So far as is known, no measurements have been reported for the particular location and meteorological conditions which were selected for this investigation.

One reason why the results obtained in this investigation are of interest in air pollution is the speculation that some of the unnaturally high ozone concentrations measured in California may be the result of natural causes, although there is little doubt that the majority of the excess ozone is due to man-made causes related to the well-known photochemical smog reactions. It has been speculated, however, that subsidence of air from the Pacific High into the California coastal areas might bring to ground level larger than normal amounts of ozone from the primary "ozone layer" found in the stratosphere at altitudes ranging from 60,000 to 90,000 feet, or from secondary or tertiary layers that sometimes exist at lower altitudes. Ozone measurements have been made in rural areas in California,[6] and in the Pacific Ocean off the coast to California[7] in an attempt to see if such a phenomenon occurs. To date, experimental evidence to support this hypothesis is lacking.

Whether this atmospheric phenomenon occurs in California or not, there is an even stronger reason for suspecting that such a phenomenon might occur in Northern Greenland. Most of the island of Greenland except the extreme southern portions and narrow strips near the shore is covered by a continuous icecap which exerts a considerable effect on the weather and atmospheric conditions of the entire area. This is illustrated in Fig. 5, which shows a cross-sectional view of the island at the latitude of Camp Tuto. As illustrated, the land elevation in some portions of the interior is below sea level so that in the absence of the icecap, the land area would actually consist of a series of peninsulas or islands.

As illustrated in Fig. 5, the air in contact with the icecap is cooled by conduction, which increases its density. This increase in density then causes the air to flow by gravity down the icecap toward the coast line. This results in consistent westerly winds along the eastern slopes of the icecap, and easterly winds along the western slope of the icecap down to Camp Tuto. Weather records obtained at Camp Tuto indicate that easterly winds occur during much of the year as a result of this effect.

As air slides down both sides of the icecap away from the center, a partial vacuum is created over the center of the icecap and air is pulled down from higher elevations. This descending air mass over the center of the icecap plus the steady transport of this air mass toward the coastal regions suggests the possibility that ozone might be brought down from the "ozone layer" in the stratosphere.

There is no information at the present time concerning the altitudes from which air is drawn down to the icecap. One previous investigator has considered this problem in analyzing data obtained in measuring atmospheric particulates over the Greenland icecap.[8] Data on particulates at ground level were compared with values obtained in the Temperate Zone at various altitudes up to 25,000 feet.[9] It was found that ground level particulate concentrations over the Greenland icecap are considerably lower than those measured in the Temperate Zone at all altitudes up to 25,000 feet. Therefore it was assumed that air is brought to ground level over the icecap from altitudes in excess of 25,000 feet, although there is no way at the present time to estimate how much higher this air might have been before it started to descend.

Thus there is no doubt that air is transported to the Camp Tuto area from the upper atmosphere over the center of the icecap. Whether abnormally high concentrations of ozone at Camp Tuto might occur in this way, however, is an entirely different matter.

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* Presented at the 54th Annual Meeting of APCA, Commodore Hotel, June 11–15, 1961, New York, New York.

Fig. 1.

First, it is not known that the air is brought to the surface from altitudes as high as the primary ozone layer at 60,000 to 90,000 feet. Second, ozone decomposes fairly rapidly under most atmospheric conditions and would not be expected to persist during the several hours that would be required to transport the air mass for 200 to 300 miles. On the other hand, the almost complete absence of atmospheric particulates and other contaminants in the atmosphere might be expected to decrease the rate of ozone decomposition. Since these factors would oppose each other, it was impossible to predict from theoretical considerations alone whether or not atmospheric transport phenomena might result in abnormally high ozone concentrations at Camp Tuto. Therefore experimental evidence was desired to attempt to clarify this point.

Experimental Procedures

A portable air pollution sampling kit (obtained from Central Scientific Company, Chicago) and related equipment were procured and transported to the Polar Research and Development Center, Camp Tuto, Greenland, by the Project Leader. This kit is designed for the measurement of atmospheric pollutants in community air pollution studies, and is illustrated in Fig. 6. Facilities are provided to collect and analyze atmospheric samples to determine total dust and particulates, nitrogen dioxide, hydrofluoric acid, chlorine, sulfur dioxide, ammonia, formaldehyde and ozone. All of these are of interest in community air pollution; the ozone measurement was of primary interest for this investigation.

The ozone measurement technique used with this kit is the potassium iodide method, which has received widespread acceptance in air pollution investigations. An alternate method of measuring oxidants (including ozone) is the phenolphthalin method.[10] A portable visual comparator has recently been made available (Hayes G. Shimp, Inc., Long Island City, New York) so that these measurements can be made in the field with a minimum of equipment. One of these comparators was obtained and taken to Greenland with the air pollution sampling kit. One of the other bubblers intended for use in measuring other pollutants was used to obtain a phenolphthalin sample, along with the potassium iodide sample. The potassium iodide sample was then measured with the visual color standards included in the sampling kit, while the phenolphthalin sample was measured with the portable comparator.

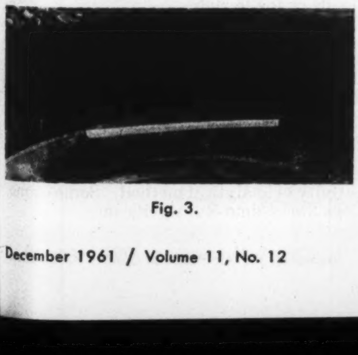

Fig. 3.

Sunlight intensity was measured with a Brockway photographic exposure meter which is designed to measure incident light. To prevent glare from the surrounding ice surfaces from causing erroneously high readings, a black, nonreflecting cylindrical shield was used over the photocell. While this method was not considered to be highly accurate, it is believed that good relative values were obtained to permit comparison of sunlight intensity at different times while sampling was in progress.

Experimental work was carried out during the period July 8, 1960 to July 12, 1960, consisting of the following:

1 Atmospheric ozone concentrations were measured by both the potassium iodide and phenolphthalin method, using the air pollution sampling equipment described previously.
2 Samples of atmospheric particulates were collected on the Millipore filters supplied with the air pollution sampling kit, and returned to San Antonio for microscopic counting.
3 Sunlight intensity was measured using the Brockway photographic exposure meter and cylindrical shield.
4 Weather observations were recorded, using a portable wind gauge and estimating other weather variables.

Item *4* was supplemented by weather data obtained at the Signal Corps MET Team Station 1, located approximately two miles east of the sampling location on the ice, and Station 3, located approximately two miles west of the sampling location on land near the edge of the icecap. These data were obtained from the National Weather Records Center.

Experimental Results and Discussion

Table I tabulates the results of runs in which measurable ozone values were obtained. Additional runs were made in which satisfactory data were not obtained due to malfunction of equipment or unfavorable weather conditions.

Fig. 2.

Due to very rapidly changing weather conditions, some runs had to be abandoned before the termination of the sampling period. In order to collect adequate amounts of ozone for analysis, it was necessary to sample for a minimum of 30 to 45 minutes, and preferably 60 to 90 minutes.

Best results were obtained with the phenolphthalin method. The intensity of the red color produced could be estimated with reasonable accuracy using the visual comparator, and it is felt that all results obtained by this method were probably accurate to within 25% or better. Considering the very low concentrations involved, this degree of accuracy could only be increased by using very precise instruments under ideal laboratory conditions.

The potassium iodide method was unsatisfactory for obtaining quantitative results. The yellow color of the solution could not be estimated accurately due to the yellowish character of the light source provided in the sampling kit. Somewhat better results were obtained by removing the standard color screen from the instrument and comparing the standard with the test solution by daylight, even though the instrument was not intended to be used in that manner. Within the very poor limits of accuracy, the results obtained by the potassium iodide method agreed approximately with the results obtained by the phenolphthalin method, although the potassium iodide values may have been in error by more than 50% of the observed value.

The Millipore filters were examined with an optical microscope, wetting a small portion of the filter with an oil having a refractive index approximately

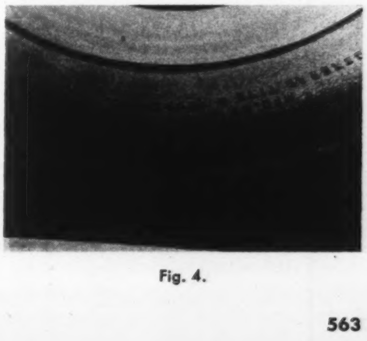

Fig. 4.

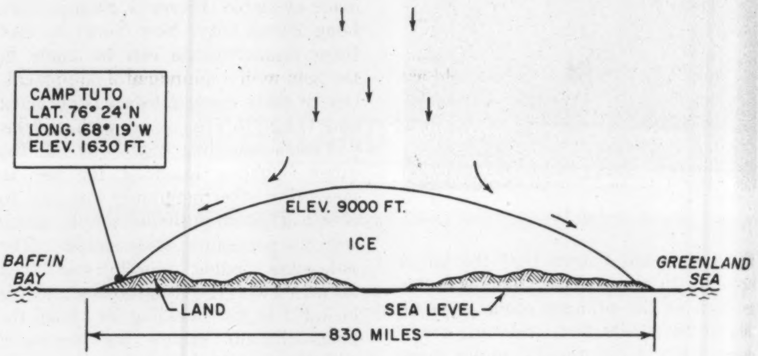

Fig. 5. Schematic diagram of air flow across Greenland.

the same as the filter material itself. This caused the filter to become almost invisible so that any particles on the surface of the filter could be counted readily. It was found that filters which had been used for continuous sampling periods of three and four hours contained the same number of particles as blank filters which had not been used for sampling, but which contained a few particles introduced accidentally in handling. Therefore, it was concluded that sampling with Millipore filters is not satisfactory for measuring the very low number of atmospheric particulates found in northern Greenland.

The best available data on atmospheric particulate concentrations in northern Greenland are probably that of Fenn, [8] who made measurements with a Cascade Impactor and with the Goetz Aerosol Spectrometer. He reports summer values of one to three particles per cubic centimeter, in a very narrow size range of about one micron diameter. He also reports winter values of less than 0.02 particle per cubic centimeter. The summer values reported by Fenn should be representative of summer conditions generally on the icecap, and indicate the probable concentration of particulates when ozone measurements were being made during this investigation. By comparison, particulate concentrations in the atmosphere over any American city would usually be many hundreds of particles per cubic centimeter, illustrating the almost complete absence of particles of any kind in the atmosphere over the icecap.

It was found that during periods of foggy or cloudy weather the ozone concentration was essentially zero. Some runs were also terminated when clouds suddenly obscured the sun after a run was started. Table I contains data for runs in which measurable amounts of ozone were detected, together with a summary of weather and other conditions.

Weather conditions as recorded during sampling were also checked with observations reported by the U. S. Army Signal Corps Meteorological Stations located at Camp Tuto and approximately two miles east of the sampling location on the icecap. During most of the periods listed in Table I, weather conditions were found to be very similar at the three locations. Cloudy weather farther east on the icecap explains several low values or zero values obtained during periods when some sunlight was observed at the sampling location.

An attempt was made to correlate measured ozone concentrations with the elevation of the sun, since elevation affects sunlight intensity. The elevation of the sun above the horizon varied from approximately 8.5° at midnight to approximately 36° at noon. However, no correlation could be made, due apparently to the overriding effects of varying cloud cover and fog on sunlight intensity. Therefore the data were plotted as shown in Fig. 7, selecting for this plot all runs when the observed light intensity at the sampling location appeared to be typical of the entire area, as indicated by similar observations at the two weather stations nearby. The correlation between light intensity and ozone concentration provides excellent evidence that the ozone being measured was formed continuously in the atmosphere, and was not brought to the area by some transport mechanism. This hypothesis is further strengthened by the fact that the ozone concentration immediately dropped to zero if the sun was obscured by clouds. This indicates that ozone is a transient intermediate in the atmosphere and that it decomposes as fast as it forms. Freedom from particulates and other atmospheric impurities does not appear to prevent the rapid decomposition of ozone. This also indicates that ozone is not transported to the Camp Tuto area from some other location, such as by subsidence from the stratosphere over the icecap, since the time

Table I—Atmospheric Ozone Measurements—Camp Tuto, Greenland

Date, July	Time[a]	Sunlight Intensity[b]	Weather Conditions	Ozone Concentration, Pphm
9	0900	250	Wind 1–2 mph, NE. Clear and bright, no limitation to visibility.	1.0
	0950	250	Same.	1.0
	1030	250	Wind 7–8 mph, NE. Clear.	1.0
	1430	64	Very light wind from E. Light fog near ground, but sun still visible.	0.2[c]
	1830	Variable	Wind 0–5 mph, NE. Light fog part of sampling period.	0.4
	2200	200	Sun bright but occasional low clouds in area.	0.3[c]
10	0945	125	Wind 4–5 mph, ESE. Partial cloud cover from high cirrus.	0.5
	1300	250	Wind 4–5 mph, ESE. Bright and clear, no clouds visible.	1.0
	1500	250	Wind 6–7 mph, E. Bright and clear.	1.3
	2100	200	Wind 8–10 mph, E. Bright and clear.	0.7
	2230	175	Wind 8–12 mph, E. Light reading doubtful due to glare from ice, increased by low solar elevation. No clouds or fog in sight.	0.4
11	—	—	Solid overcast all day. Several runs showed same result.	Zero
12	0945	125	Wind 12–18 mph, E. Thin clouds, variable.	0.7
	1030	200 max	Wind 10–12 mph, E. Variable clouds, light intensity below 100 part of time.	0.5

[a] Sampling periods varied from 30 to 150 minutes; time shown is middle of sampling period.

[b] Arbitrary scale units, read on Brockway light meter (see text).

[c] Values below 0.4 pphm were near limit of sensitivity of analytical method. Some ozone was undoubtedly present, but the numerical values are of doubtful significance.

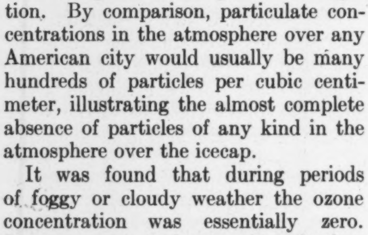

Fig. 6.

required for such transport would be great enough that complete decomposition would be expected to occur.

Thus all the data obtained during this investigation indicate that the ozone which exists in the air at Camp Tuto is formed and decomposes at that location, by the same mechanism that is responsible for the occurrence of ozone at ground level in other locations on the earth. The slightly lower values obtained compared to the Temperate Zone are apparently due to the decreased sunlight intensity, since the sun was never more than 36° above the horizon. Similar values would be expected in the Temperate Zone for similar solar elevations.

The fact that atmospheric ozone appears to decompose rapidly, even with the almost complete absence of particulates or other atmospheric impurities, is of interest in considering the possibility that abnormally high ozone concentrations in California might be due in part to natural causes. Subsidence of air into the California coastal areas from the Pacific High would normally be expected to take many hours, and ozone brought from the ozone layer to ground level would have to persist in a given air mass during this period. Yet, in northern Greenland, in what may be the purest air found at ground level anywhere on the earth, measurable quantities of ozone disappeared completely in 60 minutes or less if the sun were suddenly obscured by high-level clouds. Over the Pacific Ocean, decomposition rates would probably be at least as great, and might be increased by the presence of sea salt nuclei and other impurities that are normally present. These facts make it appear unlikely that subsidence of air from the stratosphere could bring abnormally high ozone concentrations to ground level in California, thus providing a small bit of additional evidence about the very complicated atmospheric chemical reaction mechanisms that are responsible for the well-known Los Angeles smog.

It should be mentioned also, however, that laboratory tests have produced results that are not consistent with these observations. It has been reported[11] that ozone does not appear to decompose rapidly when kept in a plastic bag in the laboratory. In conducting experiments in atmospheric chemistry, air containing low concentrations of ozone (parts per million or parts per hundred million) has been kept in flexible plastic bags for several hours, and the ozone apparently has decomposed to only a slight degree. A paper covering this work will be submitted for publication in the near future. While the reasons are not known at the present time, the results of these laboratory experiments appear to be inconsistent with the observations made in Greenland during this investigation, regarding the rapid decomposition of ozone in the atmosphere. In view of this inconsistency, one must conclude that the problem of atmospheric ozone cannot be completely resolved at the present time.

Only one possible source of error in the values obtained in this investigation has been suggested, and that is the possible effects of temperature on the phenolphthalin method. No information is available on temperature effects, but considering the conditions under which sampling was conducted, the possibility of serious errors due to this factor seems rather remote. The sampling kit was placed in an open doorway on the upwind side of a small portable building. The interior of the building was heated with an oil stove, which kept the entire sampling kit somewhat warmer than the ambient air temperature. Furthermore, during some of the runs, the sun was shining on the sampling kit which added some additional heat by radiation. A few tests were made in which the absorbing solution was warmed both before and after sampling, with no apparent change in the results. While no equipment was at hand to either control or measure the solution temperature accurately the available evidence did not indicate any important errors due to temperature effects.

So far as rubber deterioration is concerned, the amount of ozone found would be sufficient to cause cracking of tires and other rubber items in a normal environment. Considering the low ozone concentrations, however, it is a little difficult to attribute the severe cracking that was observed to ozone alone. Laboratory experiments have indicated that very low temperatures (−50°F and lower) do not cause rubber cracking. Work is now planned to see if low temperatures or other unusual environmental factors in Greenland may serve to aggravate the effects of atmospheric ozone or to cause cracking in some other way.

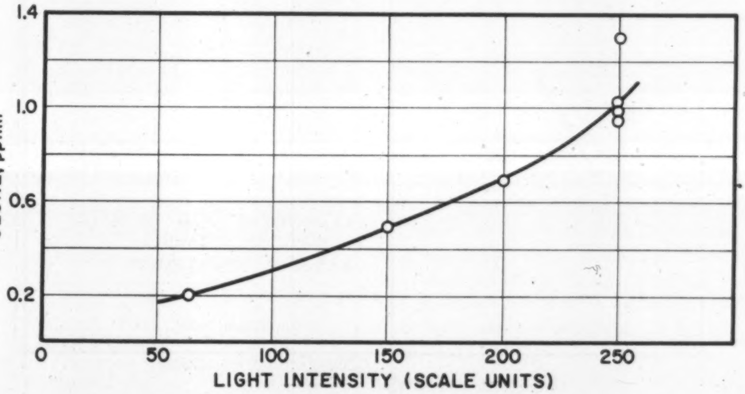

Fig. 7. Effect of light intensity on ozone concentration.

Acknowledgment

The author wishes to acknowledge the support of the U. S. Army Research Office (Durham) for the investigation described, and especially P. W. Espenschade, Ordnance Environmental Research Project Officer.

Also, appreciation is expressed to the U. S. Army Polar Research and Development Center at Camp Tuto, Greenland, for the provision of logistic support, including a portable building at the desired sampling location, batteries for electrical power, cold weather clothing, living quarters and eating facilities, and transportation to and from the sampling location.

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(*Continued on p. 584*)

The ADHESION *of Solid* PARTICLES *to Solid* SURFACES, *II**

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Adhesion of small particles to solid surfaces is a phenomenon closely associated with industrial hygiene and air pollution studies. It is involved in aerosol sampling by thermal and electrostatic precipitation, and impaction methods. It is intrinsic to the filtration process. However, a literature review[1] indicated that adhesion data for micron size particles are meager and that further experimental efforts are required to clarify roles played by particle size and shape, particle and surface material, surface roughness, ambient air relative humidity and temperature, time of particle-surface contact, and static electricity. This research was undertaken to investigate the influences of several of the above variables on small particle adhesion.

Apparatus and Procedures

Centrifugal force was used by Gillespie and Rideal,[2] Larsen,[3] and Kordecki and Orr[4] to dislodge particles from surfaces. A compressed air jet was used by Larsen,[3] Jordan,[5] and Davies, Aylward, and Leacey.[6] These methods require the investigator to convert observed parameters, i.e., centrifuge speed and air jet velocity, to particle removal force. The ingenious technique employed by Beischer[7] whereby particles coagulate to form chains with subsequent chain rupture caused by chain weight is also an indirect method calling for estimates of agglomerate length and contact area at the break point. In this study, efforts were focused on directly measuring particle to surface adhesion forces by employing micromanipulative techniques in conjunction with a microbalance.

Microbalance Description and Calibration

There is sufficient literature available[8-11] for the investigator to fabricate a quartz torsion, helical, or cantilever microbalance to measure forces in the range 10^{-1} to 10^{-4} dynes. The simplest type, the Salvoni, "fishhook,"[11] or cantilever balance was selected. Design of this balance is based on the equation for deflection of an ideal cantilevered beam.[12] Quartz microbalances were constructed and housed in a sealed glove box and held rigidly to the glove box wall by a special tool holder. The front face of the glove box was fabricated of Plexiglass, which permitted vertical microbalance deflection to be monitored by a cathetometer readable to 0.02 mm. The glove box and supporting table were mounted on special $^{3}/_{8}$ inch thick rubber base pads† to minimize vibrations. All apparatus was housed in an air conditioned laboratory.

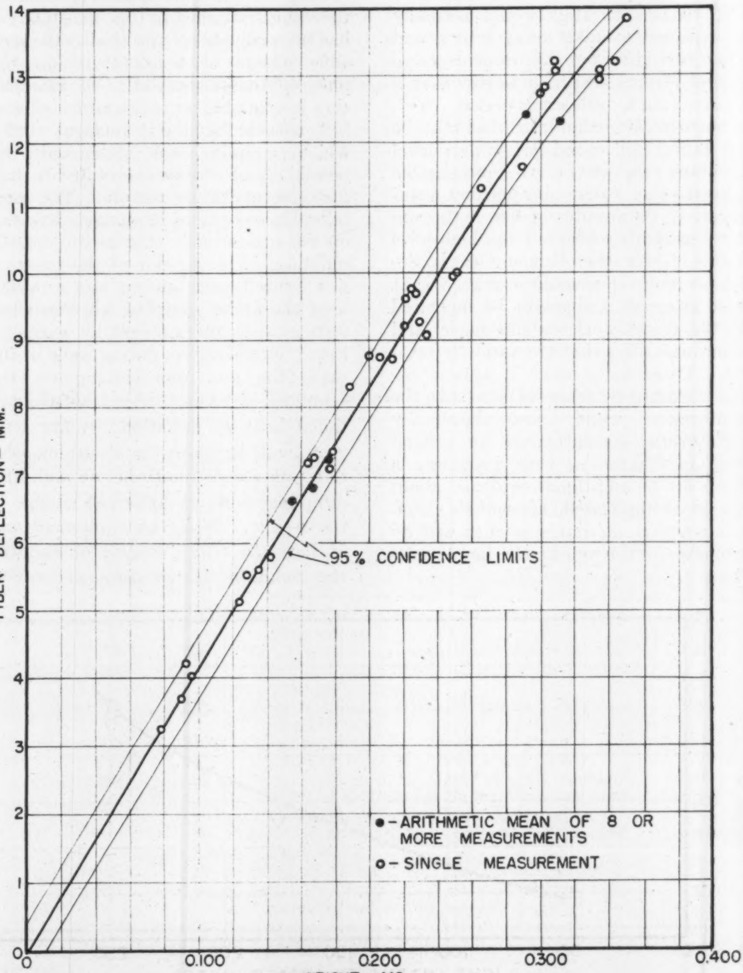

Fig. 1. Quartz cantilever microbalance fiber No. 1 calibration.

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* Presented at the 54th Annual Meeting of APCA, Commodore Hotel, June 11–15, 1961, New York, New York.

† Greene Rubber Company, Cambridge, Massachusetts.

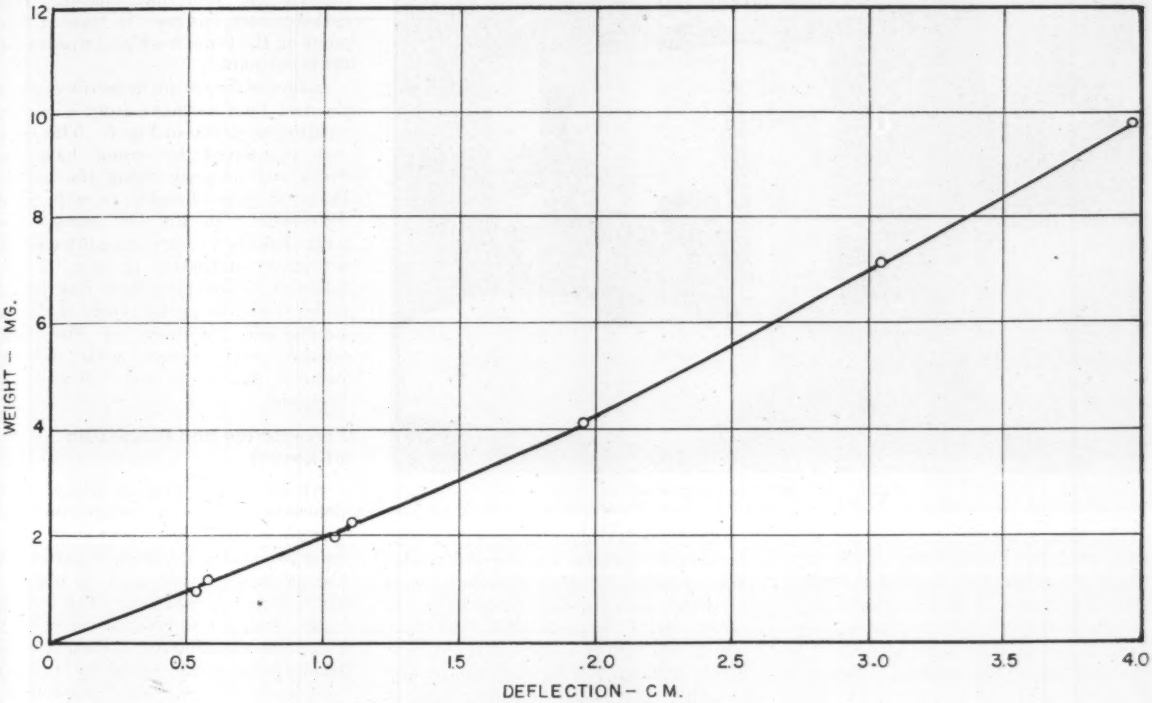

Fig. 2. Quartz cantilever microbalance fiber No. 2 calibration.

Microbalance calibration was by two techniques. First, platinum wire lengths were cut with a fine blade and sized by microscope with a Filar Micrometer. Conversion to weight per sized length was based on a platinum density of 21.37 g/cm³.[13] In the second technique, two double-edged razor blades were soldered to opposing sides of square brass stock, and the distance between outside surfaces of the blades and blade thickness was measured with a micrometer. Distance between inside blade edges was then calculated, and this distance corresponded to the length of wire cut. The average deflection of 10 wire lengths was considered the balance deflection corresponding to the measured die length. In addition to platinum wire, No. 43 and No. 40 copper wire were utilized. Calibration curves for two balance beams are shown in Figs. 1 and 2. It was necessary to apply regression analysis to calibration data of the more sensitive fiber No. 1.

Test Particle Preparation

It was decided to standardize on one particle material so that factors affecting adhesion could be systematically studied. Quartz was chosen because of widespread interest in the material, its workability, availability, and extensive literature on its properties.

By adapting techniques described by Naher,[9] it was possible to simulate either spherical or cylindrical quartz particles by starting with quartz fibers from two to forty microns in diameter,* and allowing them to "blow out" in a properly adjusted oxyacetylene flame. When the flame is properly adjusted, the fiber "rolls back" on itself, producing a spherical or cylindrical end, depending on fiber residence time in the flame and flame temperature. The fiber with simulated particle on one end was then hooked at the opposite end to facilitate attachment to the cantilever balance beam. Pyrex and platinum particles were formed in the same manner.

Test particles of quartz, Pyrex and platinum were cleaned by washing in the following baths in the sequence listed: chromic acid, demineralized water, acetone. Exposure to a water bath reversed destruction of any silanol sites caused by high temperature exposure of silica.[14, 15] Prior to cleaning, test particles were sized by optical microscopy with a Porton graticule in the microscope ocular:[16] particles were examined after completion of a test to see if they are intact.

Additional Apparatus

The remaining major component of the test system was an Emerson Model H Micromanipulator† (Fig. 3) used to hold the test surface. Vertical motion on this unit is controlled by Lever B of wheel A, as the operator desires. Lever C is a "joy stick" which causes approximately 9 mm rotational motion of the tool holder in any horizontal azimuth.

Glove box relative humidity was controlled by saturated salt solutions for extended studies of adhesion at one relative humidity, or by a dynamic system including recirculating blower and water bath with heater for studies requiring rapid changes in chamber relative humidity. Glove box conditions were determined by a wet bulb-dry bulb combination** mounted inside, and operable from outside the chamber. A circulating fan accelerated glove box equilibration.

Static charge on the balance beam,

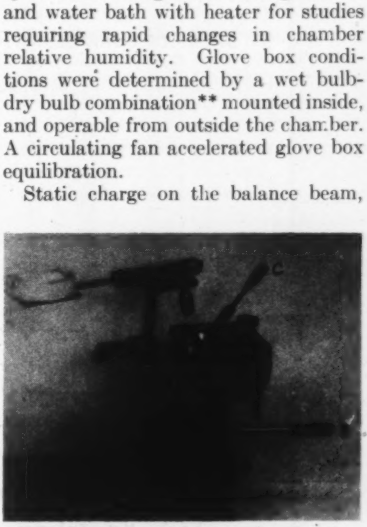

Fig. 3. Emerson Model H micromanipulator.

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* Obtainable from Thermal-American Fused Quartz Company, Dover, N. J.

† J. H. Emerson Company, Cambridge, Massachusetts.

** Model HA-2, Friez Instrument Div., Bendix Aviation Co., Baltimore, Md

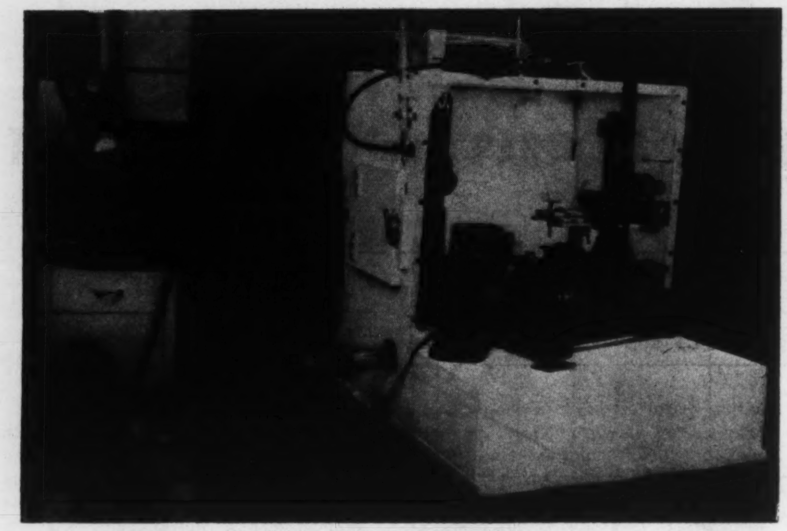


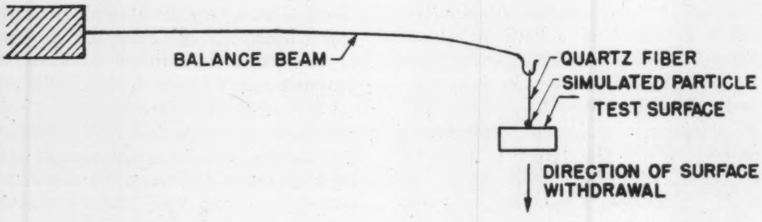
Fig. 4. Arrangement of apparatus.

or on test particle and surface, was dissipated by placing almost directly under, and in line with the beam, sources of strontium 90 or thorium metal. Reproducibility and negligible zero drift of the balance beam attest to the effectiveness of this method. Figure 4 is a photograph of the glove box with all associated apparatus.

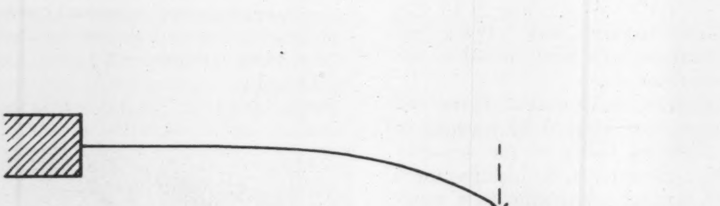
Conduction of Adhesion Tests

Force of adhesion was measured as follows. After the hooked end of a sized test fiber with particle was placed on the hooked end of the balance beam, a null cathetometer reading was taken. Zero reading of the unloaded beam occurred prior to and after tests; it never varied by more than 0.06 mm, which established the reliability of any given reading. With the aid of the chamber glove the operator gently raised the test surface by micromanipulator lever adjustment. Contact of particle and surface was monitored through the cathetometer. After the necessary contact time, breakaway was effected by slowly withdrawing the test surface on the manipulator. The cathetometer was used to track a fixed point on the beam hook and was read at the breakpoint.

Large balance beam deflections caused the test fiber to move from a vertical position as shown in Fig. 5. This effect was minimized by using long test fibers and properly sizing the balance beam to cause breakaway with small deflections. In the few cases where large deflections were encountered, the procedure indicated in Fig. 5 was followed. This procedure was judged to be workable on the basis of finding comparable adhesion of the same particle and surface with different balance beams having different deflections.



(A) AT START OF SURFACE WITHDRAWAL



(B) AT END OF SURFACE WITHDRAWAL PRIOR TO BREAK

Fig. 5. Method of compensating for large fiber deflections.

Presentation and Discussion of Results

At least four and as many as 12 determinations were made on each particle at each condition studied; at least two and as many as 10 particles of the same size were used to obtain a given force of adhesion. The average value of all measurements was taken as the force of adhesion. Dispersion of results was characterized by the percentage deviation or range, as specified.

Effect of Particle Shape on Adhesion

Types of simulated particles are shown in Fig. 6. Figure 7 indicates the extent of difference between adhesion of round and spherical end fibers to a Pyrex "flat." Average deviations for these tests were six to 26 percent. Since it was considerably easier to obtain small particles of the round end shape than of the spherical end shape, round end fibers were used in most tests.

Effect of Time of Particle-Surface Contact on Adhesion

In the literature associated with adhesion of particles to surfaces or to each other, contact time is not mentioned as an influential variable, with the exception of data presented by Bowden and Tabor[22] on time of application vs adhesion for a 0.125 inch

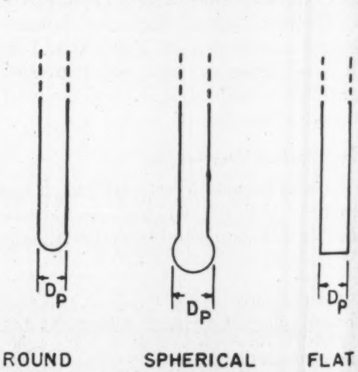


Fig. 6. Shapes of simulated test particles.

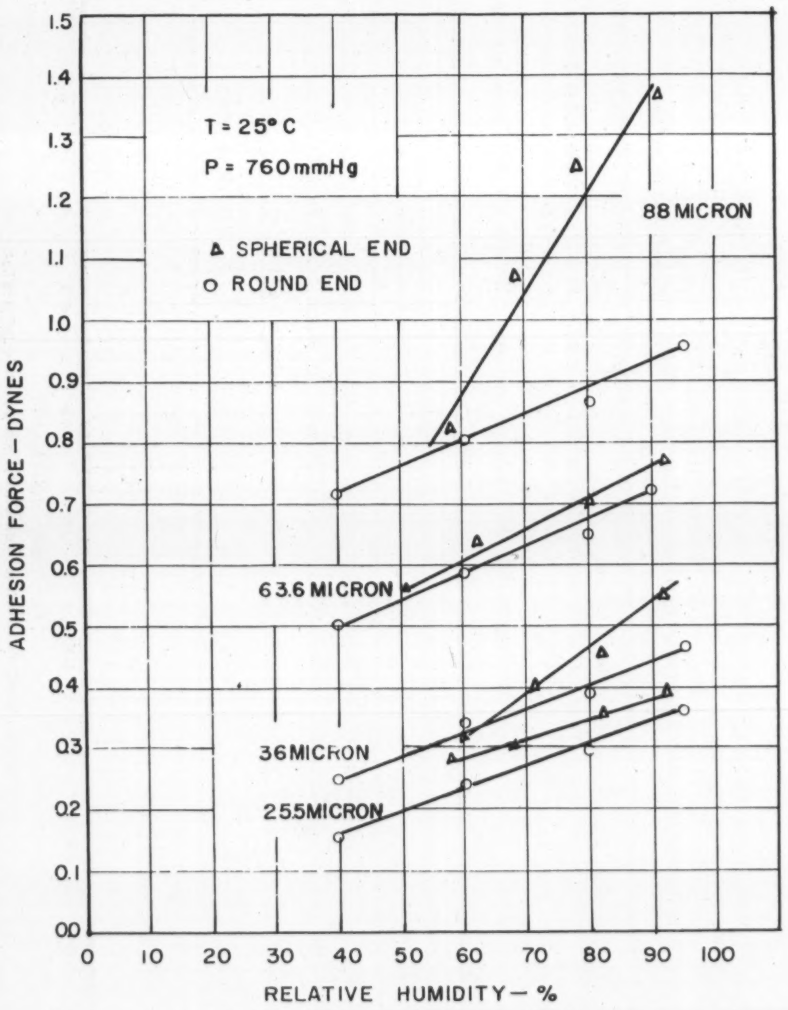


Fig. 7. Effect of test particle shape on adhesion.

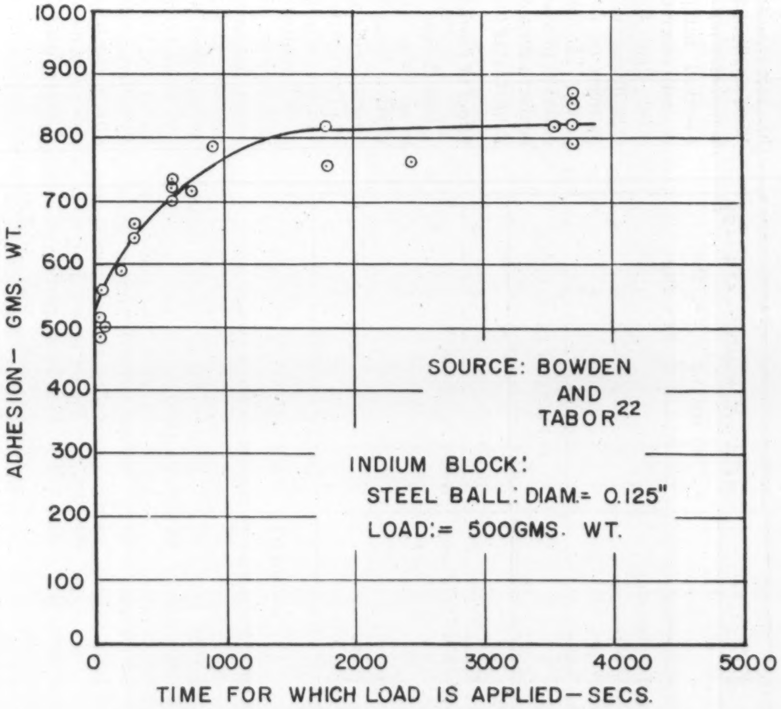


Fig. 8. Adhesion of a clean steel ball on a clean indium surface.

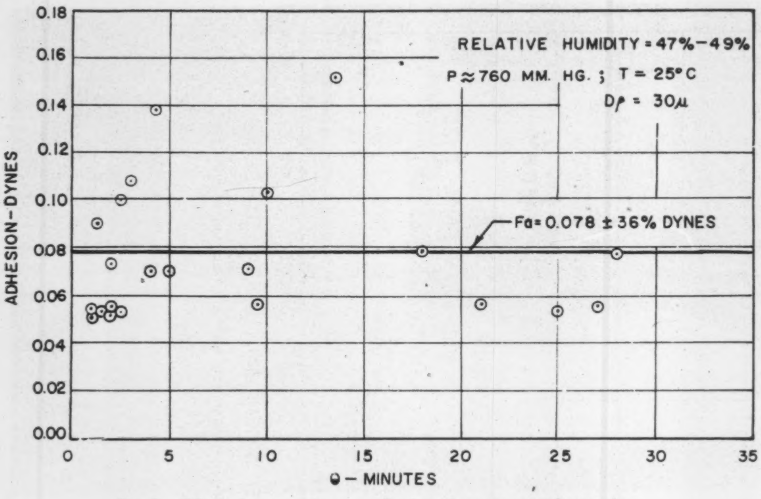


Fig. 9. Effect of contact time on adhesion of quartz particles to glass.

steel ball under 500 gm load (Fig. 8). In general, statements in the literature of small particle adhesion either ignore this effect or assume the initial force is enormous and variation of force with time can be neglected.

In this experiment variation in adhesion with contact time was of interest mainly to establish an acceptable experimental procedure. Efforts were not made to discern variation in adhesion during seconds following contact. Saturated KCNS and $Na_2C_2O_4 \cdot 2H_2O$ solutions were used to maintain glove box relative humidity while time of contact was varied from one minute to 44 hours for a given size particle. Particles and surfaces were conditioned in the chamber for 24 to 48 hours before measurements were made. Results of these tests are shown in Figs. 9 and 10.

Figure 9 is a short term study of a thirty micron particle on a glass microscope slide* for contact times up to 30 minutes. Figure 10 is a long term study of a 44 micron particle on a Pyrex optical "flat" with contact times up to 44 hours. On each figure, the average adhesion force and average deviation are indicated, as well as the adhesion force established with other particles of the same size under the same conditions. Contact times of approximately five minutes were used to obtain these latter values. On the basis of these tests, it was concluded that when using humidity conditioned surfaces, short contact times of five minutes duration yield average values of adhesion comparable to those obtained with contact times measured in hours or days.

The effect depicted in Fig. 8 was observed by Bowden and Tabor to increase with load and was attributed to "creep" of the adsorbed surface film into the deformed surface junction. With small solid particles, particle mass is probably not sufficient to rupture the adsorbed surface film and "creep" is not observed. Under conditions other than those employed in this experiment, i.e., high velocity impact of particles on a solid surface, there is greater likelihood of rupture of the adsorbed film with an enhanced time of contact-adhesion force mechanism similar to that of Fig. 8.

Effect of Particle Size on Adhesion

Particle size was a primary variable in all tests. In general, at any given relative humidity adhesion increased directly with particle size for quartz and Pyrex particles. Figure 11 indicates variation of adhesion with particle size at 95% relative humidity. The surfaces indicated are glass slides and a Pyrex optical flat with a mean surface roughness of 2159 ± 127 Angstroms.† Average deviations for these tests were two to 26 percent, and were generally higher for the glass slide than for the Pyrex flat, a result attributed to greater surface roughness variation of the glass slide. Equations for the lines drawn are: Pyrex particles-optical flat:

$$F = 0.017\,Dp$$

quartz particles-optical flat:

$$F = 0.012\,Dp$$

quartz particles-glass slide:

$$F = 0.0075\,Dp$$

where:

F = adhesion, dynes
D_p = particle diameter, microns

Effect of Relative Humidity on Adhesion

The effect of relative humidity on adhesion of quartz and Pyrex particles to a Pyrex optical flat and to a glass microscope slide was evaluated over the relative humidity range 25 to 95%. Results of these tests are shown in

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* Gold Seal Microslides, Clay-Adams, Inc., New York, New York.

† Determined with Western Electric Model No. 549, Type PAC Stylus Profilometer, Physical Research Co., Ann Arbor, Michigan.

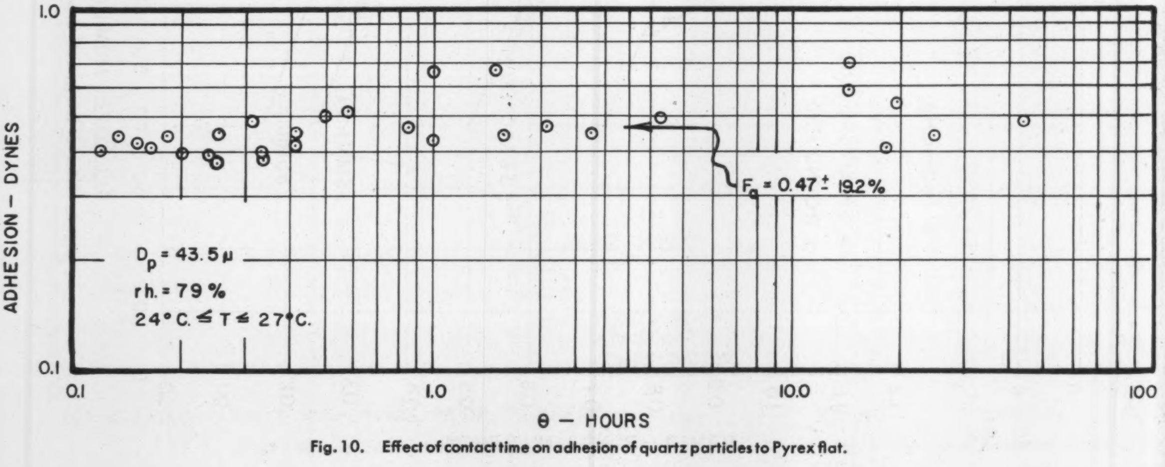

Fig. 10. Effect of contact time on adhesion of quartz particles to Pyrex flat.

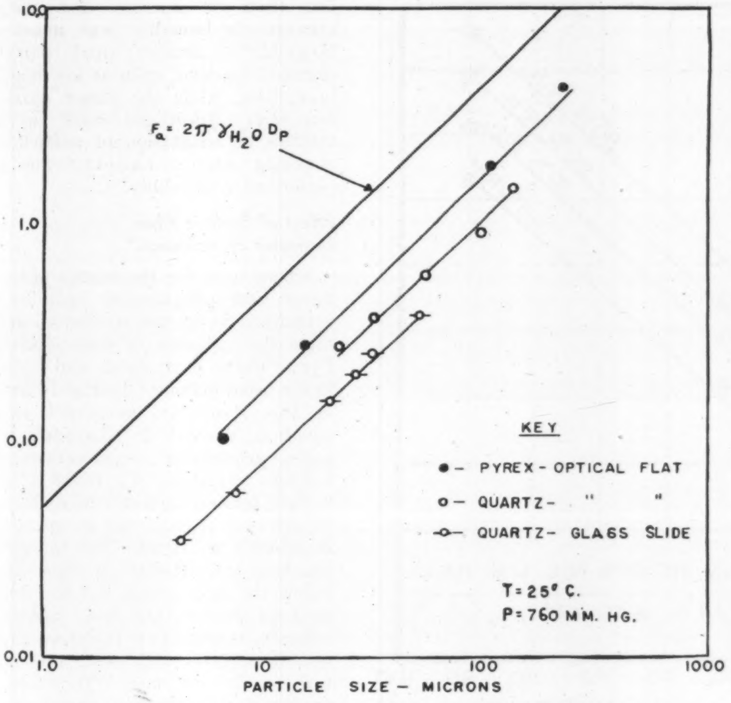

Fig. 11. Adhesion of quartz and Pyrex particles at 95% relative humidity.

Figs. 12 to 15.

Figure 12 indicates average values of adhesion as a function of relative humidity for 90μ, 51μ, 30μ, and 21μ quartz particles to the same Pyrex flat used to obtain Fig. 11 data. Average deviations increased with particle size from four to 10 percent for 21μ particles to seven to 24 percent for 90μ particles. Dispersion of results decreased with increased relative humidity.

Figure 13 is a cross plot of Fig. 12 with adhesion and particle size as ordinate and abscissa, respectively.

Figure 14 utilizes Fig. 12 data in a manner which suggests adhesion dependence on adsorption properties of quartz. Maximum adhesion in this figure refers to adhesion at 95% relative humidity obtained from the curves of Fig. 11. Percent of maximum adhesion is the abscissa, and relative humidity the ordinate of Fig. 14. Superimposed on this curve is the adsorption isotherm for quartz at 20°C as presented by Ledoux.[17]

In contrast to data for humidity conditioned surfaces, Fig. 15 illustrates a relative humidity hysteresis, or lag effect for small Pyrex particles on the Pyrex flat. As relative humidity was varied from 40 to 95% during a time interval of approximately three hours, particle adhesion was repeatedly evaluated. Figure 15 depicts traces of individual experimental points.

Increased adhesion with increased relative humidity is believed to result from increased moisture film thickness on adhering surfaces. Harkins[18] indicates mean film thicknesses of approximately three molecular layers (15 Angstroms) on quartz at saturation, with the first layer being complete at a relative pressure of 0.7. Figure 14 certainly suggests the dependence of adhesion on the adsorption properties of quartz. Further work with other materials is required to substantiate the relationship between bulk adsorption properties and strength of adhesion in humid atmospheres.

The relatively small variation in adhesion of small particles with relative humidity as compared to the behavior of particles greater than 90 microns is borne out by Fig. 15. Small particles retain moisture adsorbed at the contact interface and do not adapt as rapidly as larger particles to changing ambient air conditions. Similar behavior of sand particles greater and

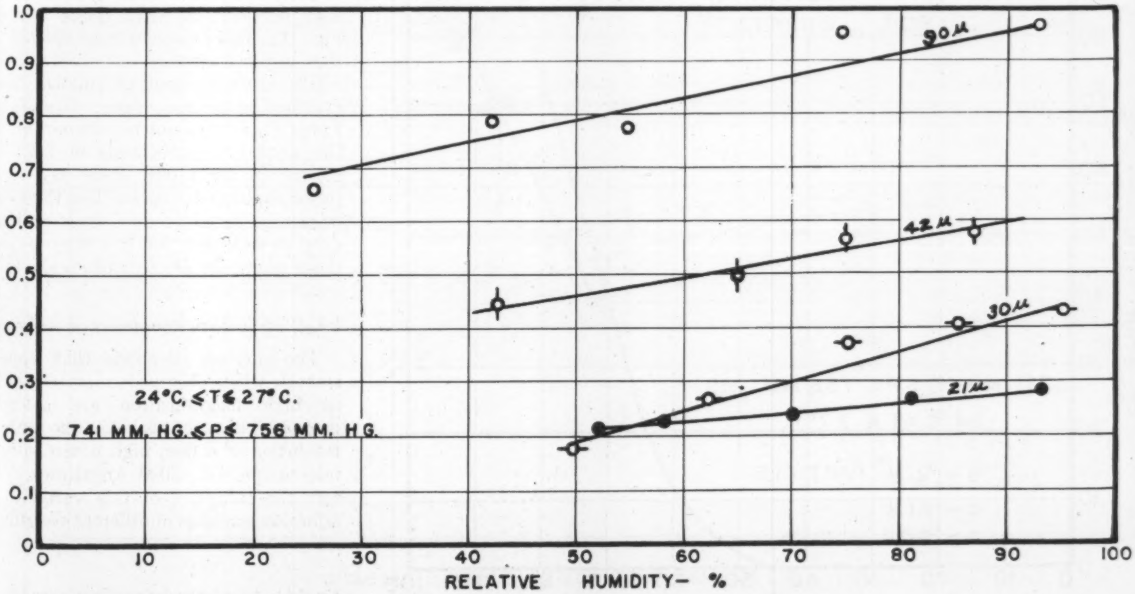

Fig. 12. Effect of relative humidity on adhesion of quartz particles to Pyrex flat.

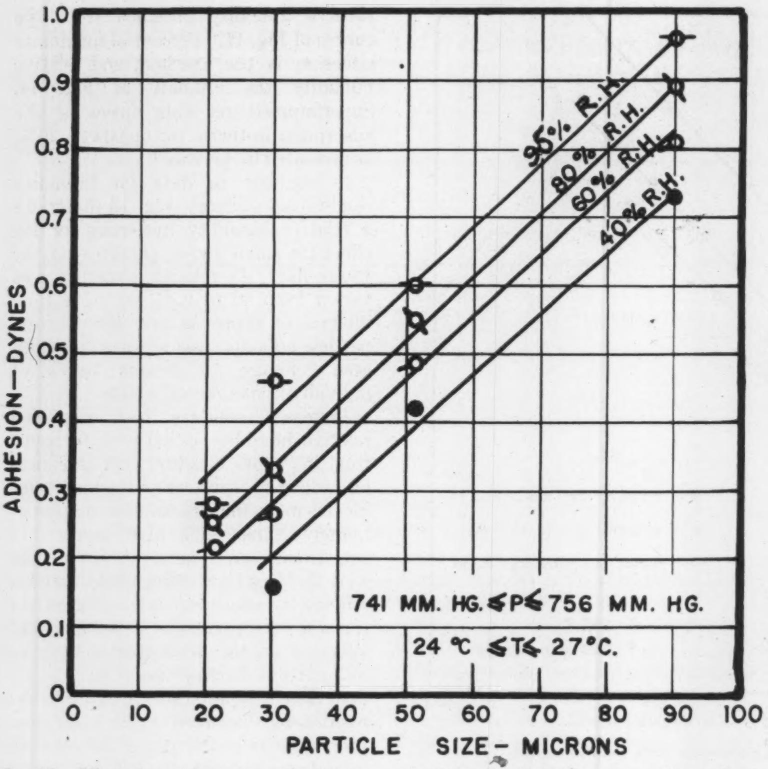

Fig. 13. Effect of particle size on adhesion at various relative humidities (quartz particles to Pyrex flat).

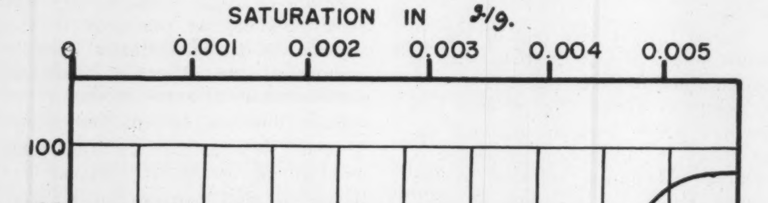

Fig. 14. Adhesion variation with relative humidity (quartz particles to Pyrex flat).

less than 80 microns diameter to atmospheric humidity was noted by Bagnold.[19] Smaller sand particles clumped together, even at low relative humidities, while the larger particles ran free. Additional work on the kinetics of adaptation of particles to changing relative humidity was not performed in this study.

Effect of Surface Fiber Diameter on Adhesion

Fibers comprise the matrix of fabric filters and adhesion of particles to cylindrical fibers was studied to determine the influence of fiber diameter. Pyrex fibers were sized and cleaned in the usual manner. In Fig. 16 results of this study are compared to an equation derived by Larsen[20] from purely geometrical considerations. In Larsen's equation, T_s refers to the surface tension of water in dynes/cm, D_p refers to particle size in cm, and F is adhesion in dynes. The theoretical equation and results of this study follow the same trend, but the former predicts higher absolute values of adhesion because it is based on ideally smooth surfaces with condensed moisture at the interface. Therefore, as predicted by theory, these results indicate that curvature of fibers composing a filter bed will result in particles adhering with less force than they do to a flat surface of the same material. This finding was tested by measuring adhesion to fabric filter materials.

Figure 17 indicates adhesion data obtained on 100% wool felt fabric used for dust filtration. Average deviations ranged from 10 to 33%. Average felt fiber diameter was 17 microns, with a range from 15 to 21 microns. Figure 16 suggests greater variation in adhesion with particle size than borne out by Fig. 17. Discrepancies may be due to the physical nature of wool fibers, which are composed of smaller hairs attached to the main fiber. Results on Pyrex fibers may not be comparable to the wool felt fabric tests of Fig. 16. Figure 18 for 1106B glass web filter paper composed of fibers less than one micron in diameter does show a sharp drop in adhesion for five micron particles where the D_f/D_p ratio is less than five.

Effect of Surface Roughness on Adhesion

The surfaces of solids that appear smooth when observed microscopically at high magnification are actually composed of asperites below the limit of resolution of a fine, high power optical microscope, i.e., 3000 Angstroms. To test the influence of this variable on adhesion, surfaces of different roughness

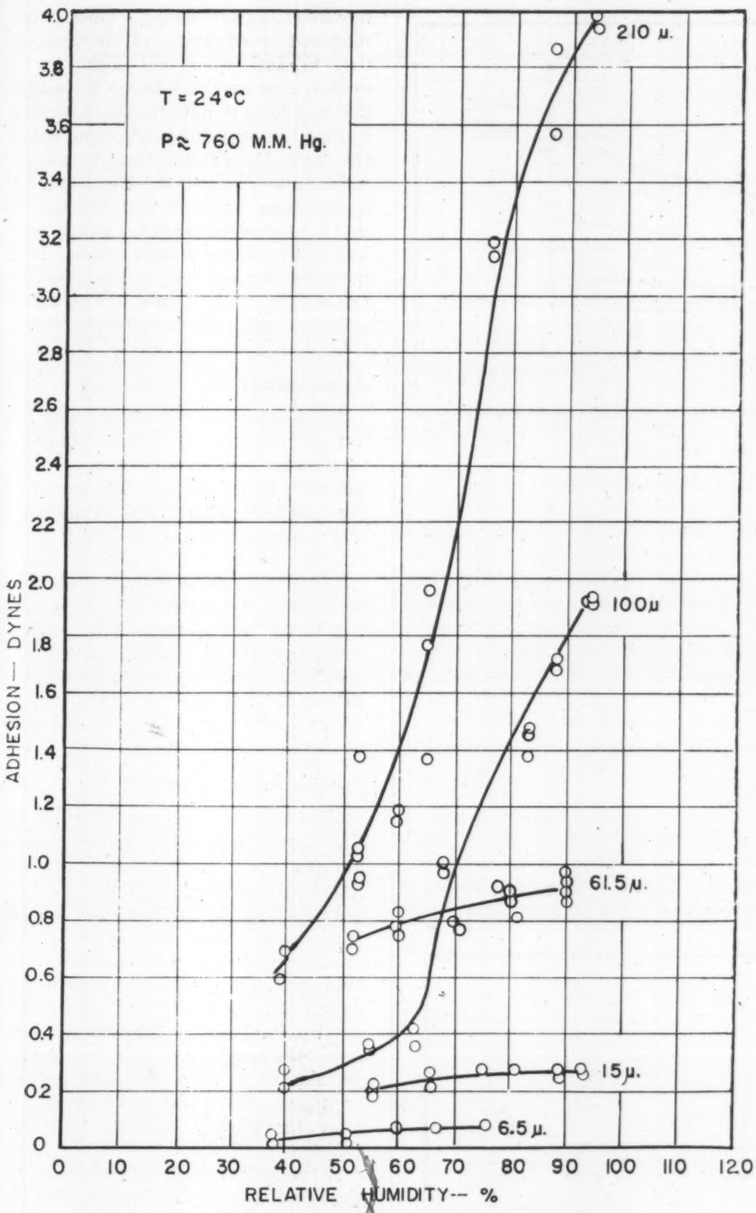

Fig. 15. Effect of fiber size on adhesion of quartz particles to Pyrex flat.

Table I—Mean Surface Irregularities of Pyrex Test Surfaces

Surface	Range of Profilometer Reading, Angstroms	Root Mean Square Surface Irregularity, Angstroms
Pyrex flat No. 1	2032–2286	2159 ± 127
Pyrex flat No. 2	2032–3810	2921 ± 127
Pyrex flat No. 3	4572–5080	4826 ± 127
Pyrex microscope slide	3048–3810	3429 ± 127

were obtained* and characterized by a stylus profilometer† (Table I).

Although test surfaces showed a range of roughness variation, multiple measurements were made and averaged to obtain characteristic adhesion forces. Average deviations were 12 to 20%. Figure 19 presents results of these tests together with the data of Bowden and Tabor.[22]

Adhesion forces for quartz to Pyrex are approximately one half those reported by Bowden and Tabor[22] for unspecified glass to glass. Reasons for this discrepancy could be the types of glass used and the techniques employed for evaluating surface roughness. Slopes of the two curves over the range of effective comparison are very nearly equal. In other words, the percentage reduction in adhesion as a function of increased surface roughness is approximately the same for the two systems. Results of this experiment can be described by the equation

$$S = (8.8 \times 10^3)e^{-0.053}A$$

$$4830 \text{ Angstroms} \leq S \leq 2160 \text{ Angstroms}$$

where:

S = average surface roughness, Angstroms

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* A. D. Jones Optical Company, Cambridge, Massachusetts.

† Western Electric Model No. 549, Type PAC, Physical Research Company, Ann Arbor, Michigan.

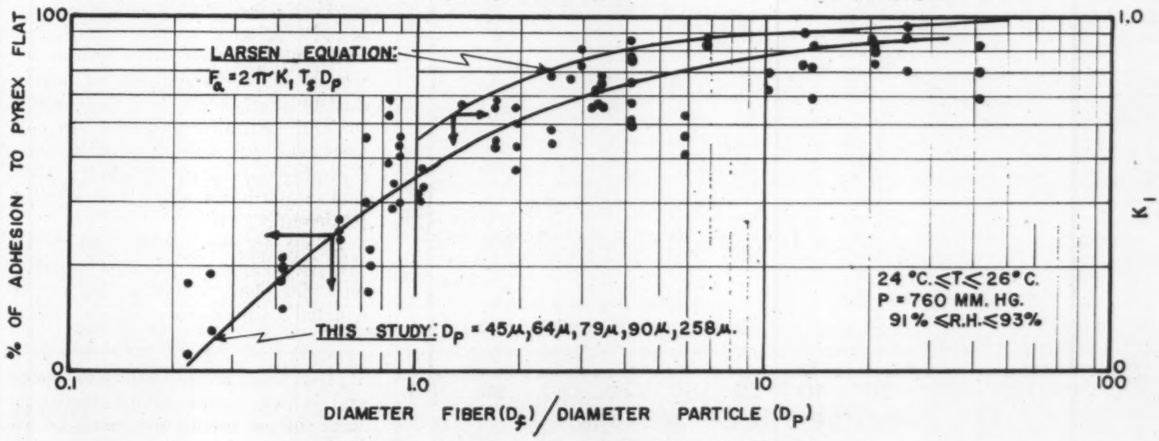

Fig. 16. Effect of fiber size on adhesion of quartz particles to Pyrex fibers.

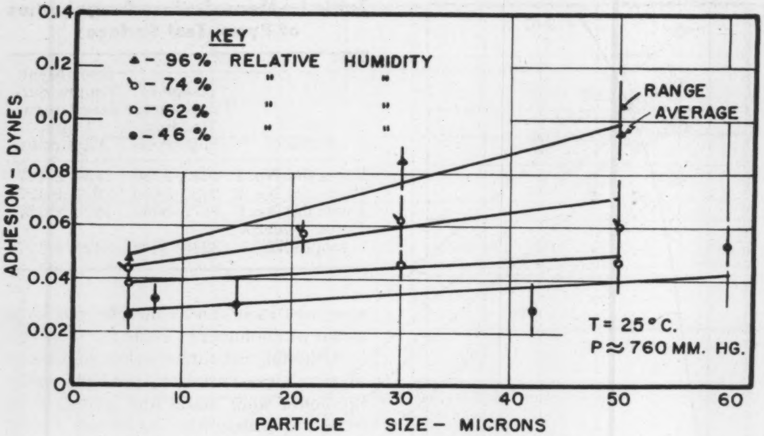

Fig. 17. Adhesion of quartz particles to 100% wool felt fabric.

A = percent adhesion based on equation

$$F = 2\pi\gamma D_p$$

where:

F = perpendicular adhesion force, dynes
D_p = particle diameter, microns
γ = surface tension of water, dynes/cm

Determination of the Force Required to Slide Quartz Particles

Instead of imparting sufficient downward vertical motion to the test surface to cause particle breakaway, the micromanipulator was used to initially move the surface downward and then move it in a horizontal direction. A calibrated graticule in the cathetometer ocular enabled the observer to calculate the fiber angle θ at which particle sliding began. The horizontal force acting on the particle could then be calculated from the known vertical force acting on the particle.

Forces required to initiate sliding of quartz particles on a Pyrex flat* were highly variable. Thus, for a 50-micron particle horizontal shearing forces from 0.02 to 0.21 dyne were required to initiate sliding. These forces represent coefficients of friction of 0.04 to 0.45, where the coefficient is defined here as the ratio of horizontal shearing force to initiate sliding divided by the perpendicular adhesion force. Orr and DallaValle[24] report comparable forces required to slide or roll 25- to 50-micron particles from the tips of pointed metal rods inserted axially into jets of air. These studies indicate that particles residing on a solid surface exposed to an air stream will certainly slide or roll before becoming re-entrained.

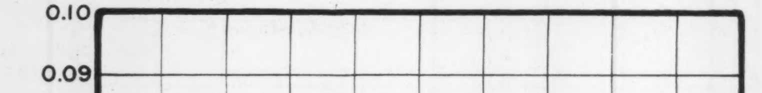

Fig. 18. Adhesion of quartz particles to 1106B glass web filter paper.

Applications

Application of adhesion data is limited because a single spherical particle to surface contact is rarer in practice than contact between surfaces and irregularly shaped particles and agglomerates. However, if it is reasonable to assume that a single spherical particle to surface contact is responsible for adherence, the above results can be used to estimate particle dislodging forces. Thus, if the accelerating force perpendicular to the surface is a cm/sec², and dislodgement occurs when the adhesion force is equaled or slightly exceeded, then:

$$F_{\text{adhesion}} = F_{\text{dislodging}} = \text{ma} = 1/6\pi D_p^3\rho_p$$

The accelerating force could be due to a rapper such as those used on bag filters or to centrifugal action.

From Fig. 11 a 50-micron quartz particle on a glass slide at 25°C, 760 mm Hg, and 95% relative humidity is held by a force of approximately 0.5 dyne. If $\rho_p = 2.6$ (g/cm³), $a = 3100$ gravity forces to dislodge the particle from the surface. This calculation pertains to a spherical quartz particle on a glass slide and may be grossly in error for other materials or particle shapes.

Air re-entrainment of particles residing on a flat plate was treated by Kordecki and Orr[4] and this writer elsewhere[1] has considered entrainment of particles on a circular cylinder in a turbulent air stream. The former case relates to re-entrainment of settled dust by wind, while the latter pertains to fabric filtration of dusts. In each treatment, assumptions must be made regarding the nature of velocity variation within the boundary layer adjacent to the wall.

If the forces presented above are assumed to apply to particles impacting on a flat plate, kinetic energy can be equated to the force of adhesion. Thus,

$$K.E. = {}^1/_2 mV^2 = F_{\text{adhesion}}$$

If the collision is completely elastic and particle kinetic energy exceeds the force of adhesion, the particle will bounce. Gillespie and Rideal[21] ap-

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* 2160 ± 127 Angstroms mean surface roughness.

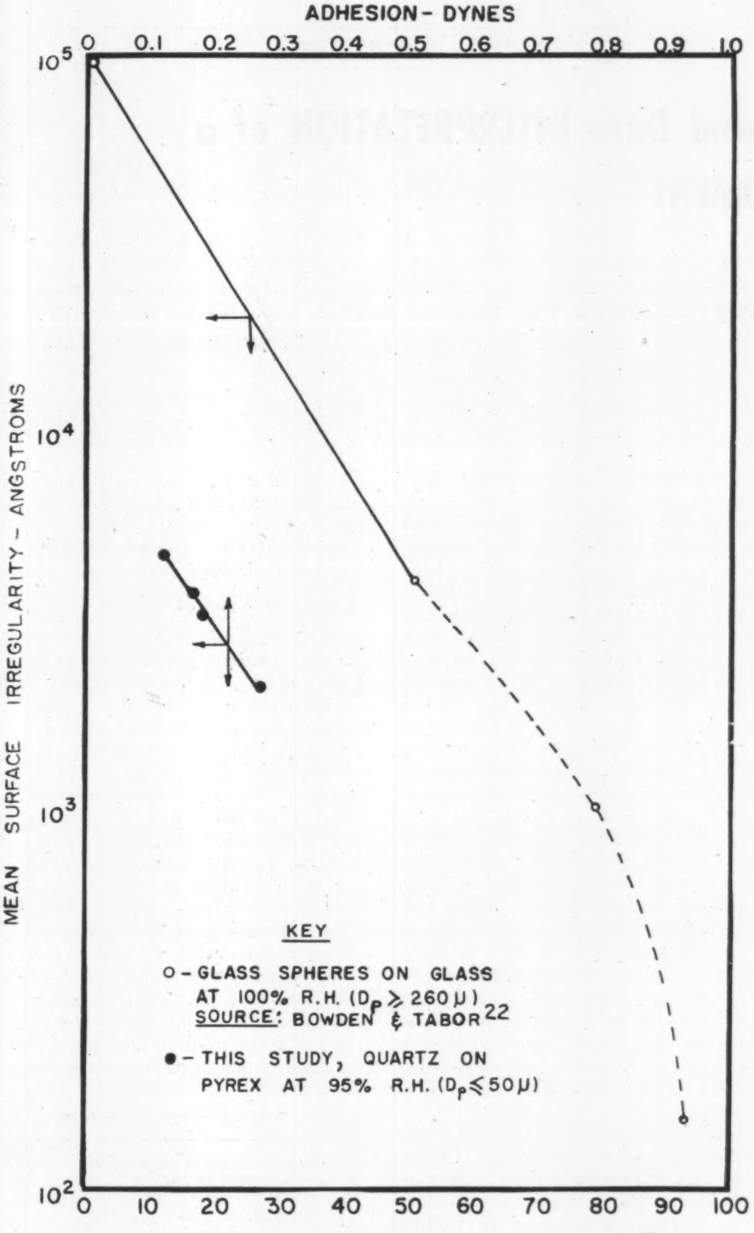

Fig. 19. Effect of surface roughness on adhesion.

proached this problem but estimated adhesion forces from Hertzian deformation of the solid surfaces. Ranz, Talandis, and Gutterman[23] considered only the mechanics of particle bounce. Jordan[5] attacked the problem and estimated adhesion from data obtained by Bradley[25] with fused quartz spheres. These approaches can now be reconsidered with regard to adhesion forces measured in this experiment.

Summary

Forces of adhesion of simulated quartz and Pyrex particles on solid surfaces were measured by a technique employing a micromanipulator and microbalance in a glove box. Adhesion phenomena were found to be probable in nature, requiring statistical parameters for specification. A particle and surface will adhere with different strength on multiple contacts, which may be due to nonhomogeneity of particle and surface with associated different points of contact. Therefore, when speaking of forces of adhesion the average force is implied.

For contact times up to 44 hours, time of contact of humidity conditioned simulated quartz particles and Pyrex surfaces did not significantly alter the force of adhesion if contact time was at least five minutes.

Adhesion of simulated quartz and Pyrex particles to various surfaces increased directly with particle size at any relative humidity employed. Adhesion differed for particle and surface material and prediction of adhesion when only particle size is known is not possible. Other work, not reported here,[1] substantiates this conclusion.

Adhesion decreased with relative humidity and this reduction appeared to be related to bulk adsorption properties of particle and surface. Further work with other materials will be necessary to substantiate this point.

Adhesion of simulated quartz particles to Pyrex rods was dependent on the parameter (diameter of rod/diameter of particle). Particles exhibited 50% of their adhesion to a Pyrex optical flat when this ratio had a value of 2.0. Adhesion measurements with 1106B glass web filter paper indicated that this variable is influential when particles adhere to fabrics used for filtration. Wool felt fabrics, which have a more complex fiber structure, did not clearly demonstrate this effect.

Adhesion of quartz particles to Pyrex surfaces decreased with increased surface roughness.

Horizontal shearing forces required to slide quartz particles on Pyrex were highly variable. They were characterized by coefficients of friction of 0.04–0.45, where the coefficient is defined here as the ratio of horizontal shearing force to initiate sliding divided by the perpendicular adhesion force.

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(*Continued on p. 584*)

Dynamic CALIBRATION *and Data* INTERPRETATION *of a Light-Scattering* INSTRUMENT*

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The property of light-scattering by particulates has been widely applied in air pollution work by determining the optical density of spots formed on filter tapes[1] and by measuring the scattered light intensity from single particles in air for counting and sizing purposes.[2] Measurement of scattering from clouds of aerosols can yield information concerning the total amount of suspended matter in relation specifically to visibility effects and generally to air pollution levels. To make distinctions as to kind of suspended matter, e.g., fog versus soot, auxiliary determinations are required. In any case, an instrument achieves maximum utility when its response is calibrated in terms of a fundamentally acceptable parameter.

The Monitron is a commercially available photometer designed specifically to measure 90° scattering of aerosols.[3] It has been available for about two years. It is the purpose of this paper to describe methods and results of studies concerning performance and response calibration. The work was done using the first commercial model. While the engineering in the latest models has been considerably improved, the principle of its operation remains the same and the results of our study apply. Specific aims of the study were: (*1*) to determine the effect of air flow rate on response, (*2*) to find the relationship between instrumental sensitivity setting and response, and (*3*) to calibrate response in terms of optical density of aerosols.

General Description of Monitron

Figure 1 is a block diagram to illustrate the operation of the instrument. The light source (L) is collimated along the scatter beam (S) and the monitor beam (M). The chopper disc (D), which has a ring of holes, alternately illuminates the two beams. When (S) is illuminated, only scattered light reaches the phototube. The commutator (C) attached to the same shaft as rotating disc (D) separates the signals from the scatter beam (S) and the monitor beam (M). Checks before and after the study confirmed effective separation of signals. The signal from M enters a feedback circuit and determines the gain on the photomultiplier. The signal from S is indicated by the meter. The meter is provided with a linear scale from 0 to 100. Ten and 50 mv recorder output connectors are supplied. The sensitivity control, provided with an arbitrary circular scale from 0 to 200, rotates a plane mirror through 90° and thereby adjusts the intensity (I_m) of the monitor light beam reaching the phototube. Photomultiplier gain is inversely proportional to I_m. Although scattered light intensity (I_s) is a function of incident light intensity, the feedback mechanism obviates need for light source regulation. Thus, the response signal is proportional to the fraction of incident light scattered at 90° from an aerosol in the optical volume.

Light is scattered in an aerosol by gas molecules and by suspended matter. The proportion of molecular scatter increased rapidly at higher sensitivities. The instrument response to particle free air as a function of sensitivity is given in Fig. 2. Thus, the scattering response (R_p) produced by particles alone is expressed by

$$R_p = R_t - R_m \qquad (1)$$

where R_t is the total response and R_m is the molecular scatter response. R_m as a function of sensitivity was very reproducible from time to time as indicated by the points in Fig. 2. All aerosol response data in this paper refer to R_p.

For general operation of the instrument, a blower at the air outlet pumps air through the black box (9 in. wide, 21 in. long, 10 in. high). Design of the black box in this early model of the Monitron did not prevent leaks. To overcome this interference, filtered compressed air was used to maintain controlled air flows.

Source of Aerosol

Hydrosols of uniform polystyrene spheres obtained from the Dow Chemical Company, Midland, Michigan, were used for the production of test aerosols. The six particle sizes employed had the following diameter, in microns: 0.188, 0.264, 0.365, 0.557, 0.814, 1.171. Aliquots of concentrated suspensions were diluted to about 0.05 to 0.10 mg/cc with double-distilled, membrane-filtered water. This represented approximately a 1:1000 dilution of the original suspensions received from Dow. In efforts to minimize the occurrence of large agglomerates in the hydrosols, they were centrifuged subsequent to dilution and immediately prior to aerosolization. The actual concentration of polystyrene in the hydrosol was obtained from turbidity measurements

Table I—Nomenclature

c = proportionality constant
d = diameter of particle
E = optical density per unit length
I_0 = incident light intensity
I = transmitted light intensity
I_b = light intensity of monitor beam before traversing aerosol
I_m = light intensity of monitor beam incident on phototube
I_s = scattered light intensity incident on phototube
k = defined by equation (3)
K = scattering coefficient, which is the ratio of effective scattering and geometric particle diameters
L = length of optical path in suspension
N = concentration, numbers per unit volume
OD = optical density
r = radius of particle
R_m = response due to molecular scatter
R_p = response due to particle scatter
R_t = actual response due to aerosol
s_0 = s intercept when $\log R_p = 0$
s = sensitivity setting

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* Presented at the 54th Annual Meeting of APCA, Commodore Hotel, June 11–15, 1961, New York, New York.

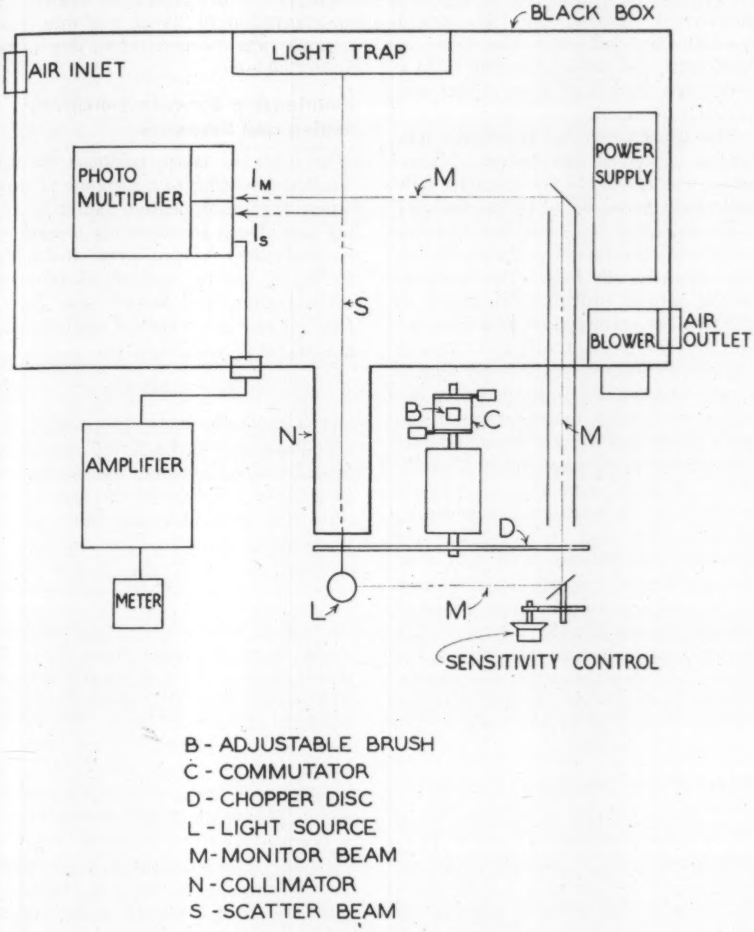

Fig. 1. Monitron light scatter photometer.

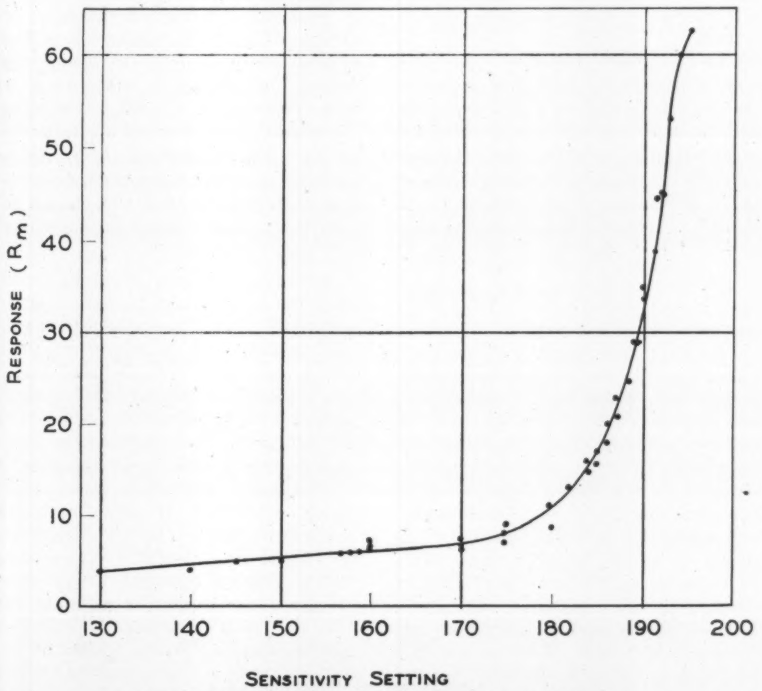

Fig. 2. Effect of sensitivity setting on response to particle free air.

at 525 mμ and calibration charts previously prepared for each particle size. Knowledge of hydrosol concentrations was used to program aerosol concentration.

Generation of Aerosol

The aerosol was generated at a constant rate by means of an air blast atomizer.* The operation of this generator involved atomization with humidified air which aspirated the hydrosol from an external reservoir. Reflux from the walls of the atomizer was returned to the reservoir. Because most of the aspirated and atomized hydrosol refluxes from the walls, the humidified air was necessary to prevent evaporation and to maintain the concentration of the hydrosol constant. The pressure of the aspirating and atomizing air was maintained at 450 ± 1 mm Hg above atmospheric by means of a Nullmatic pressure regulator.[4] The specific primary air pressure varied with the absolute and relative sizes of the air and liquid jets. In these experiments, the air jet had an exit orifice of 0.3 mm and the liquid jet had an exit orifice of about 0.5 mm so that at 1210 mm Hg the primary air volume was 4.0 l/min (corrected to 760 mm Hg at 21°C). Dried secondary air was introduced at the exit of the atomizer to evaporate the water from the mist containing polystyrene particles. An approximate minimum of 10 liters of air per minute was required for evaporation. Aerosol concentrations were adjusted by variable dilutions with secondary air and by changing the concentration of the hydrosol. Interfering particulates were removed from the house compressed air by cotton filters about 23 cm long.

Sampling

The aerosol passed into a 43 cm long, 4.6 cm inside diameter duct to the Monitron. A 1.9 cm inside diameter sampling probe opening into the sampling stream 9.5 cm ahead of the entrance to the Monitron black box was employed for withdrawing aliquots alternately with a membrane filter and the Goetz aerosol spectrometer. A 47 mm membrane filter disc (Millipore HA type) clamped into a pyrex filter holder suitably connected to the probe was found satisfactory. In the first series of experiments the filter sampled at 5.3 l/min and in the second series at 3.75 l/min at 760 Hg and 21°C. The aerosol spectrometer was operated at 24,000 rpm using 0.03 in. jets and balanced pressure conditions employing the AIHL modification.[5] The corresponding inlet flow rate was 3.65 l/min. Foil number 1-60 was used consistently for the collection of polystyrene for mass determination.

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* Detailed specifications are available from the authors.

While sampling aerosol, the duct flow rate was 22.4 l/min corresponding to a linear velocity of 1340 cm/min. The probe flow rate of 5.3 l/min corresponded to a velocity of 1870 cm/min, and the probe flow rate of 3.75 l/min corresponded to 1330 cm/min. Thus, isokinetic conditions were practically met.

The sampling time for the filter and the aerosol spectrometer was about one hour each and was measured to the nearest minute. At the end of the sampling period for mass determinations, a five or 10 minute sample was obtained with the aerosol spectrometer for determining the relative particle size distribution of the aerosol. When concentrations were changed by known dilution with secondary air, the mass determination was carried out for only one dilution and was calculated for the others.

Aerosol Analysis

Prior to use for polystyrene sampling, the membrane filters were exhaustively extracted to remove chloroform soluble material which produced background in the wavelength regions of polystyrene absorption. Because the interfering material had volatility and because the membrane filters tended to shrink on exposure to chloroform a special extraction procedure was developed.

To purify the membrane filters, a circular flat glass rack was made to level off the bottom of a 50 mm diameter soxhlet extraction tube. The protective parchment was removed from 100 membrane filters. The filters were then stacked parchment side up with a cellulose filter pad every 10 membrane filters and with one pad at the bottom and another at the top of the stack in the extraction tube. A watch glass at the top weighted the stack down. The extraction was carried out with 200 cc of reagent grade chloroform at five cycles/hour. After one hour the extract in the reservoir was replaced with new chloroform. It generally required four to five hours to reduce the absorbence of a 200 cc extract to 0.04 at 278 mμ in a 10 mm cell. At the end of the extraction period the tube was drained, the watch glass was removed, and the entire stack of membrane filters was lifted by means of forceps and transferred to a 10 cm petri dish. The top of the petri dish exerted sufficient pressure to prevent shrinkage during evaporation of chloroform overnight at about 30°C.

After sampling the polystyrene aerosol, the membrane filter was rolled and inserted into a two cc volumetric flask, which was then filled with chloroform. After 18 hours a U.V. spectrum of the solution was obtained in a 50 mm microcell between 245 and 300 mμ. The polystyrene deposit on the aerosol spectrometer foil was dissolved in chloroform and reduced to one cc in a volumetric flask and a spectrum was similarly obtained.

The spectra revealed that some contaminating aerosol was present. Microscopic analysis of the spectrometer foils indicated this aerosol to be less than 0.1 μ in diameter, so that considerably more of it was retained on the membrane filter than on the foils. The contaminating aerosol probably originated as the result of entrained oil mist from the air line filters as the result of continuous operation. However, sufficiently characteristic spectra of polystyrene were obtained to permit quantitation of the peak at 269 mμ using a baseline background correction suggested by Cooper.[7] From standard curves $C = 1.54\ A$, where C is the concentration in mg/cc of chloroform and A is the baseline absorbence at 269 mμ in 50 mm cells. Comparisons of recoveries on membrane filters and spectrometer foils indicated them to be equivalent. Therefore, the aerosol concentration was calculated from the spectrometer foil samples. The oil mist did not interfere with the light-scattering determinations of the test polystyrene aerosol.

Effect of Air Flow Rate

In order to obtain an estimate of aim 1, an aerosol containing 0.814 μ diameter particles was generated and the Monitron response at a sensitivity of 185 was measured while varying the secondary air flow rate. An increase in the total air volume should yield a proportional decrease in aerosol concentration.

The corrected response (R_p) decreased linearly as total flow rate was increased from 7.2 to 22.5 l/min. At 39.5 l/min the response was greater than predicted, indicating that either the flow rate affected response or that a response below 10 was not linear instrumentally. In either event, the data indicated that in the region of linear response, the response was independent of flow rates up to 22.5 l/min.

Relationship Between Sensitivity Setting and Response

In order to relate response at one sensitivity setting to a response at any other, the multiplication factor of R_p per unit change in sensitivity needed to be established. From curves analogous to Fig. 2, but for aerosols of different concentrations and particle size, $R_p = f\ (s)$ for any given aerosol followed the general exponential equation

$$R_p = c \exp k's \qquad (2)$$

and logarithmic plots of s versus R_p were linear provided $s \leqq 190$, and $R_t \geqq 10$. For simple utility, the value of k ($k = 2.3\ k'$), should be independent of scattering intensity. In other words the slope

$$k = \frac{\log R_p}{s} \qquad (3)$$

should have the same value over the usable range of s for any given aerosol. The usable range of s depends on the intensity of scattered light. The intercept (s_0) was obtained when extrapolating plots of log R_p versus s. s_0 is an inverse function of scattering intensity. The relationship between k and s_0 is given as a linear regression curve in Fig. 3. This indicates k to decrease with decreasing s_0, implying that the light scattering intensity of the aerosol affected the value of a given instrumental sensitivity change.

To explain this fundamental defect in design, let I_b be the intensity of the monitor beam before traversing the aerosol and assume its value to be a linear function of s. After traversing the aerosol, I_b is decreased by scattering to I_m. Attenuation of I_b increases exponentially with increasing concentration of aerosol so that the change in gain for a unit change in sensitivity

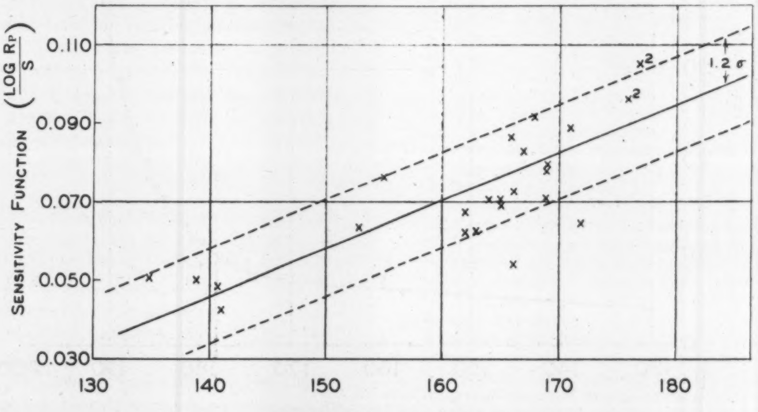

Fig. 3. Relationship between functions of concentration and instrumental sensitivity.

Table II—Response to Polystyrene Aerosol as a Function of Particle Size and Concentration

Nominal Particle Diameter									
Sensitivity = 170						Sensitivity = 175			
0.188 μ		0.264 μ		0.365 μ		0.557 μ		0.814 μ	
μg/m³	R_p	μg/m³	R_p	μg/m³	R_p	μg/m³	R_p	μg/m³	R_p
782	12	466	14	845	33	512	22	405	12
868	14	519	14	895	35	578	23	449	13
968	15	579	15	999	37	568	25	501	14
1093	16	655	16	1130	40	634	30	566	16
1380	22	818	19			641	25	708	20
1752	29	1049	22			716	29	916	27
						718	32		
						896	46		
						925	40		
						1150	50		
						1300	54		

Table III—Scattering Coefficients (K) of Polystyrene Particles in Air (Calculated from Curves by Whitby, *et al.*)

Particle Diameter, μ	K
0.188	0.5
0.264	1.4
0.365	2.4
0.557	4.2
0.814	3.7
1.171	2.4

setting continuously decreases. This difficulty may be solved by directing the monitor beam to the photocell without traversing the aerosol by the use of a lucite or fiber glass light tube.

The conversion equation, to determine R_{p2} from R_{p1} when the sensitivity is changed from s_1 to s_2, is given by

$$\log R_{p2} = k\,(s_2 - s_1) + \log R_{p1} \quad (4)$$

The mean value of k in Fig. 3 was 0.071 ± 0.014. This means that a sensitivity adjustment of 10 units changed the response by a factor of approximately five.

Response to Model Aerosols

Table II gives the responses obtained with five particle sizes. One point, not listed in the table, was obtained at 220 μg/m³ for an aerosol containing 1.17 μ diameter particles. Thus, data were obtained at mass concentrations ranging from 220 to 1300 μg/m³. This range is analogous to concentrations found in urban atmospheres. From the largest to the smallest sizes the number concentrations ranged from about 10^2 to 5×10^5 particles per cc. These concentrations yield ratios greater than 100 for distance of separation over radius. At ratios greater than 100, particles scatter light independently of one another.[6]

The data in Table II indicated a linear relationship to response for each particle size. From a point of equal mass concentration for each particle size, the response per particle was calculated. As shown by Fig. 4, the response per particle was directly proportional to the square of the diameter. This relationship was calculated by Gucker and Rose[8] from Mie theory for right angle scattering using 0.51 μ radiation, and it has been found empirically for 90° scatter from single particles by O'Konski and Doyle[2] for white light. Figure 4 is evidence that the Monitron responded in accord with accepted light scattering theory.

The optical density of nonabsorbing spheres per unit length of optical path in a suspension can be rewritten:[6]

$$\frac{1}{L} \log \frac{I_0}{I} = \frac{OD}{L} = E = 2.3\,K\pi r^2 N \quad (5)$$

Substituting particle diameter for radius and simplifying, equation (5) becomes

$$E = 0.341\,Kd^2N \quad (6)$$

K values for polystyrene particles in air having a refractive index of 1.60 were estimated from curves by Whitby, et al.[9] These values are given for different particle sizes in Table III. They are based on calculations using Mie equations and 0.524 μ radiation. E was calculated by substituting appropriate numbers for K, d, and N corresponding to the mass concentrations given in Table II. Then, E and R_p were plotted in Fig. 5 for two sensitivity settings. By regression analysis based on least squares, the equation for the correlation at $s = 170$ was

$$E = 1.18\,R_p \quad (7)$$

and when $s = 175$ the equation became

$$E = 1.06\,R_p \quad (8)$$

The results of the correlation indicated that the Monitron response varied linearly to changes in optical density of aerosol. By use of the calibration curves at the indicated sensitivity settings, the optical density per meter of aerosol was determined with a standard deviation of about ±6%.

Sources of Error

Several sources of error, both nonsystematic and systematic, existed in this calibration study. The nonsystematic sources of error in the calibration system included: (*1*) existence of doublets and triplets of nominally sized particles, which would reduce the value of N and have an effect on K, (*2*) precision of aerosol generation, and (*3*) sampling and analysis. The systematic error was produced by using monochromatic radiation K values instead of white light K values. Refinements of the calibrating system are feasible, if this approach to the calibration of aerosol photometers is acceptable. More rigorous calibration makes sense only after gross instrumental sources of error have been eliminated. These sources appeared to be primarily in the nonlinearity of k and in backlash in the sensitivity control. Errors in the graphical estimation of k and s_0 contributed to the deviation in Fig. 3.

Discussion

The type of calibration study using known dynamic systems as described here has the advantage of studying and testing the instrument under simulated conditions analogous to intended applications. It provided opportunity to discover design defects and operational problems, to establish calibration data, and to consider the meaning of the instrument response.

The use of a chopped beam to control photomultiplier gain and to nullify the effect of light intensity fluctuations is simple and effective, provided the control or monitor beam does not traverse the aerosol. Re-routing of the monitor by means of a light conducting tube is recommended. The backlash problem to improve reproducibility and to prevent drift of sensitivity control can be solved by use of higher quality gears or by a direct friction shaft. The need for a continuous monitor beam intensity control by means of a rotating mirror is

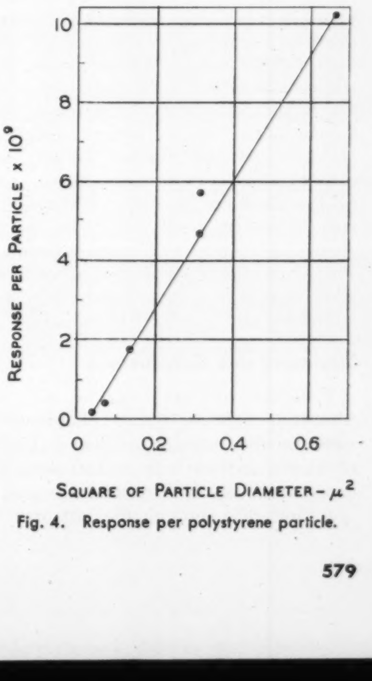

Fig. 4. Response per polystyrene particle.

questioned. The employment of optical screens selected to attenuate the monitor beam for response level changes in steps of one half or one decade may permit more simple and reproducible operation. Mechanical commutation created problems in proper separation of signals as commutator brushes wore and dust tended to short circuit the contacts.

Whether our attempt to calibrate the response to 90° light-scattering in terms of the optical density of an aerosol has validity is subject to discussion. For the aerosol employed in this study the results indicated empirically a linear relationship. It would be interesting to determine if the oscillating functions of the Mie equations are suppressed upon integration for white light illumination of aerosols heterogeneous with respect to size distribution, refractive index, absorption characteristics, and shape. When Mie equations were applied to calculations using monochromatic radiation and single particles, characteristic response curves were complex.[6] Similar calculations with integration over the spectral region of white light for 180° and 90° scattering from single particles reduced the magnitude of response oscillations.[7] Thus, the heterogeneity with respect to aerosol composition is expected to emphasize linear relationships between scattering at any angle and optical density. If this is true, then the response from any instrument based on scattering or turbidity measurements can be translated to equivalent terms after calibration.

Comparative studies with various types of instrumentation using different kinds of known aerosols are needed. Previous studies[10] on outside atmospheres attempting to determine correlations between results obtained with different instruments suffered from the disadvantage that the properties of the aerosol were not known. At times the correlations were qualitatively good and at other times they were poor. Comparative performance with respect to known aerosols is important because in addition to instrumental variables several factors affect the optical density of a dispersion. These factors include: (*1*) particle size distribution, (*2*) particle concentration, (*3*) particle shape, and (*4*) gas phase composition. Changes in optical density may occur due to a change of any one or all of these factors. Pinpointing factors responsible for any given change in optical density requires additional and specific determinations.

Summary and Conclusions

Dynamic calibration studies with a Monitron light-scattering photometer were described using polystyrene aerosols of known particle size and at several concentrations. The results indicated:

1 Flow rate through the instrument up to 22.5 l/min had no effect on response.

2 The photomultiplier gain controlling beam needs to be diverted in order to by-pass the aerosol and to establish linearity in gain change per unit change in sensitivity setting. A suitable modification was suggested.

3 A 10-unit change in sensitivity setting produced approximately a five-fold response change.

4 Instrument response varied linearly with concentration for a given particle size in concentration regions of incoherent scattering.

5 Instrument response varied linearly with the square of the particle diameter.

6 Instrument response varied linearly with the calculated optical density of the aerosol.

7 Calibration of all light scattering devices in terms of optical density will enable direct comparison of relative measurements.

Acknowledgments

The willing help of a number of people is very much appreciated. Among these, Messrs. F. Yoon and R. Martin bore the major brunt of the laboratory work, Dr. W. Gaffey and Miss J. Thomas advised and carried out some of the statistics, Dr. M. Papadopoulos made valuable suggestions, Mrs. Stevenson produced the graphic art, W. Gong advised on manuscript corrections, Mrs. Tocchini and Miss Humphrey typed and expedited copy. Dr. Helwig provided continued encouragement throughout.

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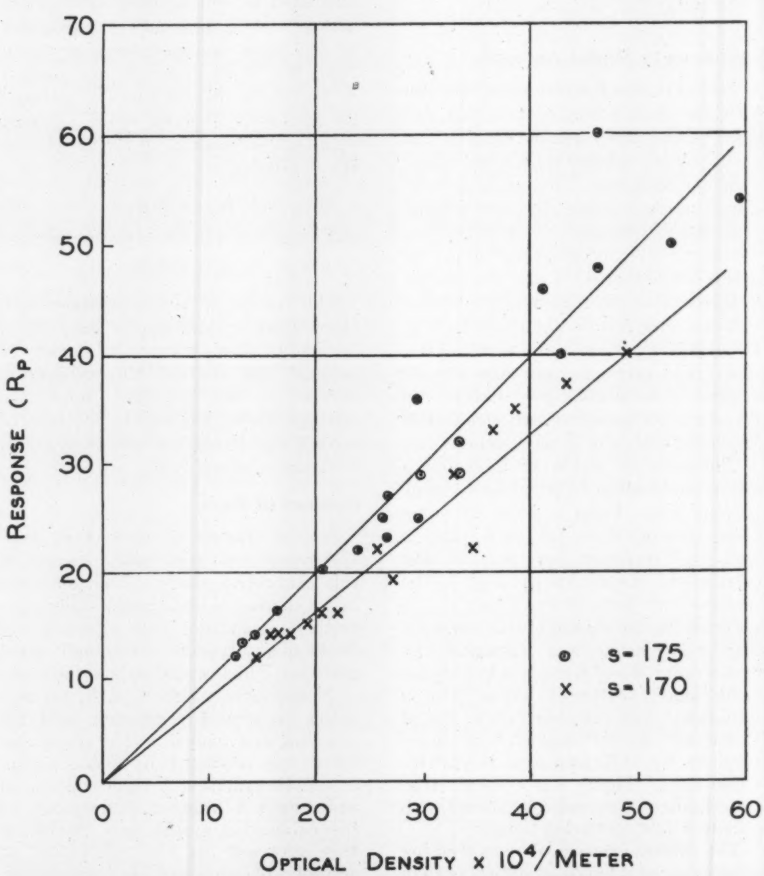

Fig. 5. Comparison of calculated optical density to response.

The EFFECT *of* TEMPERATURE *on* PHOTOCHEMICAL OXIDANT PRODUCTION *in a Bench Scale Reaction System*[*,†]

FORREST C. ALLEY,[**] M.S., P.E., Research Associate, and **LYMAN A. RIPPERTON**, Ph.D., Assistant Professor,
Department of Sanitary Engineering, School of Public Health, University of North Carolina

In the 10 or so years since Haagen-Smit[1] proposed the photochemical mechanism for ozone formation in the lower atmosphere considerable effort has been made to determine the exact nature of the "smog reaction." A great number of the variables affecting this reaction have been demonstrated. Previous work at the University of North Carolina has produced evidence that close temperature control may be quite important during studies of oxidant production in synthetic atmospheres. Since this possible temperature effect is contradictory to the fact that photochemical reactions normally have a small or negligible temperature dependency,[2] a literature search was made to learn if oxidant production had been investigated at various temperatures. Failure to locate the results of such a study prompted the investigation described below.

Experimental

Materials

Hexene-1 of 99 mol percent purity obtained from the Phillips Petroleum Company was used as the olefin. Nitrogen dioxide was obtained in cylinders from the Matheson Company. Chemicals used in preparation of the Mast ozone meter solution were as prescribed by the instrument manufacturer.

Apparatus

A gas phase reaction system was constructed which utilized one 72-liter pyrex flask as the reaction chamber and a similar flask as the surge chamber (Fig. 1). The two flasks were enclosed in a cabinet lined with aluminum foil and equipped with a one-half ton air conditioner for cooling and two infrared lights for heating. Each flask contained a mylar propeller mounted on a stirring bar for mixing

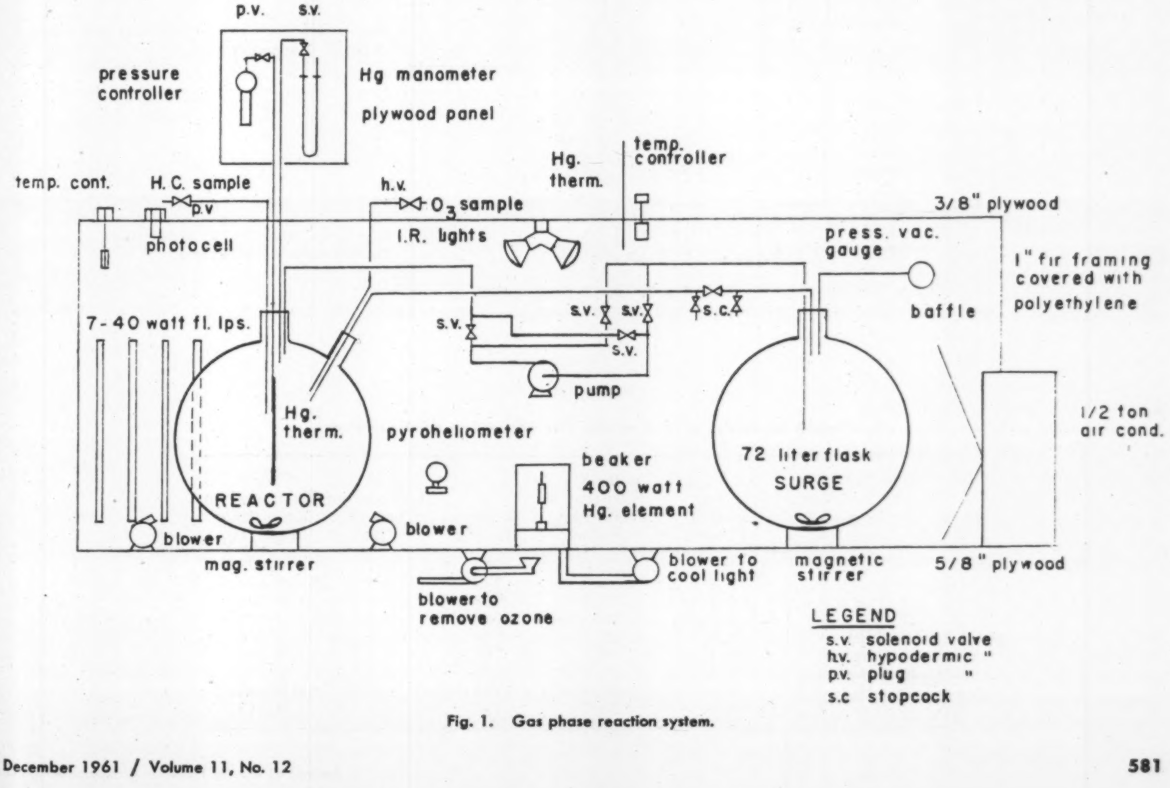
p.v.
s.v.
pressure controller
Hg manometer
plywood panel
temp. cont.
H. C. sample
p.v
h.v.
O3 sample
Hg. therm.
temp. controller
3/8" plywood
photocell
I.R. lights
press. vac. gauge
1" fir framing covered with polyethylene
7-40 watt fl. lps.
s.v.
s.v.
s.v.
s.c.
s.v.
baffle
pump
Hg. therm.
pyroheliometer
1/2 ton air cond.
beaker
400 watt Hg. element
72 liter flask
SURGE
REACTOR
blower
blower
mag. stirrer
blower to cool light
magnetic stirrer
5/8" plywood
blower to remove ozone
LEGEND
s.v. solenoid valve
h.v. hypodermic "
p.v. plug "
s.c stopcock

Fig. 1. Gas phase reaction system.

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[*] Presented at the 54th Annual Meeting of APCA, Commodore Hotel, June 11-15, 1961, New York, New York.

[†] This project was supported in part by the University of North Carolina Research Council, in part by the U. S. Public Health Service, National Institutes of Health, Research Grant No. RG6653(R1), and in part by an Air Pollution Traineeship Award from the Public Health Service, U. S. Department of Health, Education, and Welfare.

[**] Present Address: Dept. of Chemical Engineering, Clemson College, Clemson, S. C.

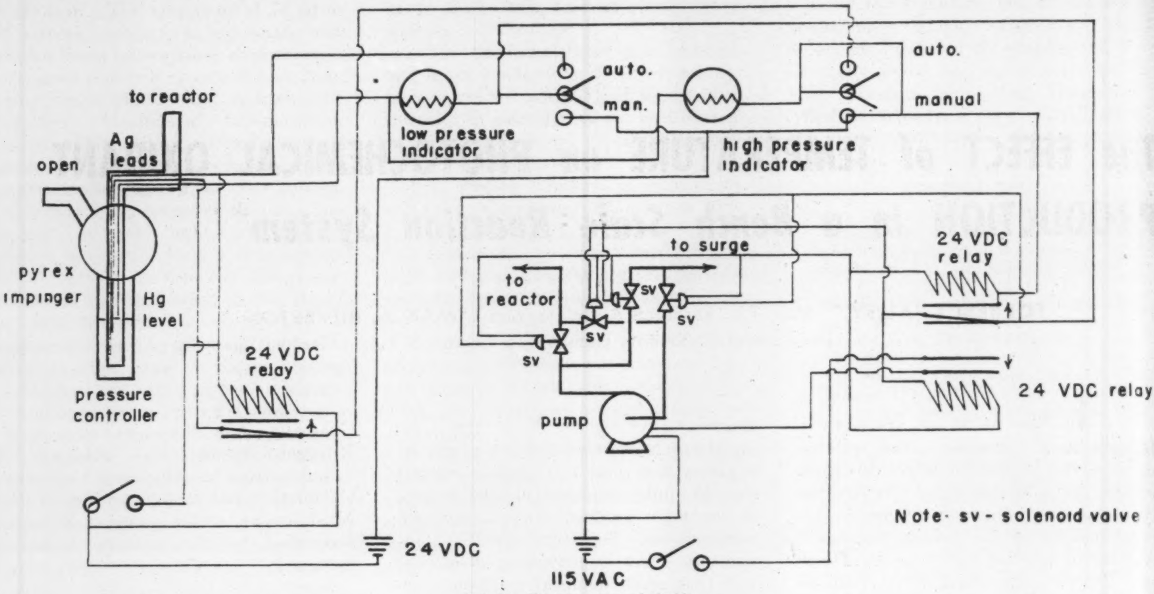
to reactor
Ag leads
open
pyrex impinger
Hg level
pressure controller
24 VDC relay
24 VDC
low pressure indicator
auto.
man.
high pressure indicator
auto.
manual
to surge
to reactor
sv
sv
sv
sv
24 VDC relay
24 VDC relay
pump
115 VAC
Note- sv - solenoid valve

Fig. 2. Pressure control circuit.

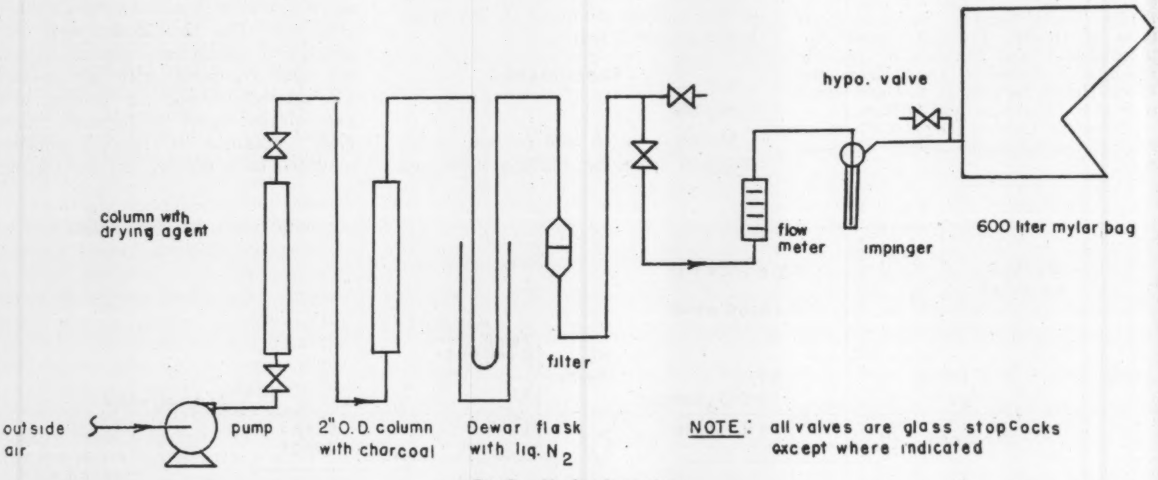
column with drying agent
outside air
pump
2" O.D. column with charcoal
Dewar flask with liq. N_2
filter
flow meter
impinger
hypo. valve
600 liter mylar bag
NOTE: all valves are glass stopcocks except where indicated

Fig. 3. Air cleaning system.

Table I—Data and Results for Nine Irradiation Runs

	Av Temp °C	Initial Oxidant Pphm	Peak Oxidant Production Pphm	Av Press Mm Hg	Init Hydrocarbon Concent Ppm	Av Hydrocarbon Reac Rate Ppm/hr
(1)	13.7 ± 0.3	11.8	4.0	754	2.1	0.098
(2)	13.5 ± 0.5	7.7	6.2	749	2.1	0.174
(3)	13.9 ± 0.6	8.4	2.9	758	2.1	0.062
(4)	25.1 ± 0.3	8.8	10.0	753	2.1	0.333
(5)	25.1 ± 0.3	9.5	12.2	759	2.1	0.336
(6)	25.0 ± 0.2	6.1	12.1	764	2.1	0.304
(7)	34.9 ± 0.4	8.8	29.2	768	2.1	0.290
(8)	35.2 ± 0.3	9.4	29.4	754	2.1	0.286
(9)	35.0 ± 0.2	8.5	28.7	759	2.1	0.315

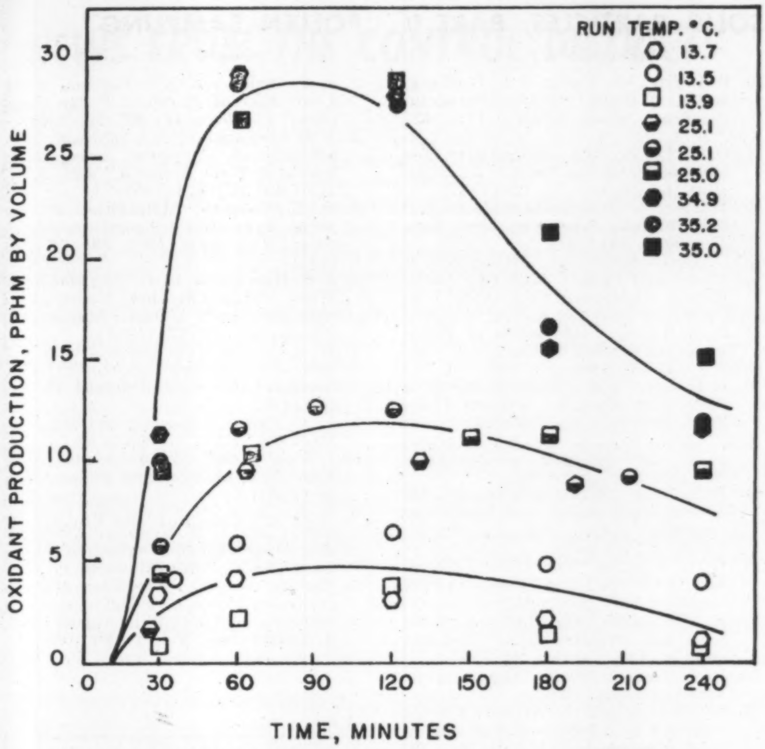

Fig. 4. Oxidant production versus time of irradiation (system pressure 750–764 mm).

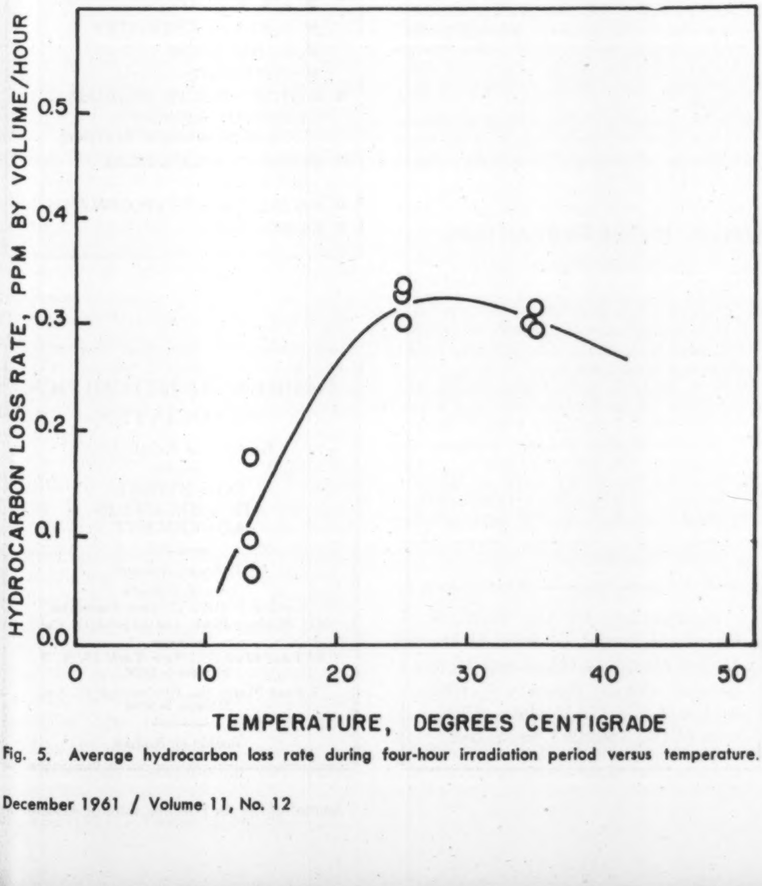

Fig. 5. Average hydrocarbon loss rate during four-hour irradiation period versus temperature.

In addition, the reaction flask contained a mercury thermometer which could be read through a slot in the front of the cabinet. The reaction flask was surrounded by three blowers to provide for rapid thermal equilibrium. The temperature in the cabinet was automatically regulated by two separate controllers mounted in two different locations in the cabinet.

The pressure in the reaction flask was maintained by a pump and solenoid value arrangement activated by a pressure controller (Fig. 2). The pressure differential in the reaction flask could be maintained within one to two millimeters of mercury. The surge flask was maintained at atmospheric pressure by constantly bleeding some of the original charge mixture into it from the mylar blending bag. Any gas withdrawn from the reaction flask was immediately replaced by a nearly identical mixture from the surge flask. Withdrawal of a 30-cc sample was sufficient to activate the pressure control system.

The two flasks were irradiated by light from a 400-watt mercury lamp and seven 40-watt fluorescent lamps. The envelope was removed from the 400-watt lamp and the element recovered with a four-liter beaker. Air was blown at a constant rate into the beaker to remove heat produced by the lamp. The intensity of light in the cabinet was measured with an Eppley pyrheliometer and a photocell. The pyrheliometer reading was about one-tenth that for summer solar radiation.

Procedure

Air for blending the olefin-nitrogen dioxide charge mixture was cleaned and dried by passing it through a drying agent, activated charcoal, liquid nitrogen freezeout, and a fiberglas filter (Fig. 3). The air volume was measured with a calibrated rotameter. Each blend consisted of 480 liters of air to which was added five cc of distilled water to produce an absolute humidity of 0.0085 gm water per gram of dry air.[3] The hydrocarbon content of the humidified air was measured with a Carad flame ionization hydrocarbon analyzer. Five microliters of hexene-1 were added from a pipette by inserting the pipette into a small nalgon tube just upstream from the mylar bag. The blend was mixed by recirculating the mixture through a carbon vaned pump for about five minutes. Upon removal of the pipette a syringe valve was inserted in the nalgon tube and sufficient nitrogen dioxide injected to produce a nine to 11 pphm reading on the Mast ozone meter.

The mixture was then bled into the evacuated surge and reaction flasks. As soon as the entire system reached atmospheric pressure, the pressure control system was checked for satisfactory operation. The entire system was then evacuated again and refilled with the charge mixture. An initial oxidant and hydrocarbon sample were then taken and the lights turned on. Oxidant and hydrocarbon readings were taken at 30-minute intervals for one hour then at hourly intervals for three hours. The ozone meter was allowed to sample from the reactor for about 10 minutes prior to taking a reading.

Results and Conclusions

The tabulated results of nine irradiation runs are given in Table 1. The oxidant production is shown in Fig. 4 as a function of time of irradiation and temperature. Oxidant production was calculated by subtracting the initial oxidant reading before the lights were turned on from the oxidant reading at the particular sample interval. The peak oxidant production was approximately doubled for each 10 degree temperature increase.

The average hydrocarbon reaction rate for each four-hour irradiation period is plotted against temperature in Fig. 5. The rate increased sharply as the reaction temperature increased from 13.5 to 25°C, then decreased slightly as the temperature increased to 35.0°C.

From these results it is concluded that the peak oxidant production occurring during the irradiation of olefin and nitrogen dioxide mixtures is dependent on the reaction temperature. The magnitude of this temperature effect is of the same order as that which would be predicted for a thermal reaction.

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(*Continued from p. 565*)

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Season's Greetings

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(*Continued from p. 575*)

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Booklet on Request

NEWS FROM THE CONTROL DISTRICTS

Bay Area

The new Chief Administrative Officer for the six-county Bay Area Air Pollution Control District will be D. J. Callaghan according to an announcement by Mrs. Clarissa Shortall McMahon, Chairman of the Board of Directors.

He was selected for the position from a total of 91 applicants, seven of whom were interviewed personally by the entire Board at an all-day session yesterday. Mr. Callaghan, a native of the Bay Area, was graduated from the University of California in Berkeley 1938. Prior to his new appointment, he has been Director of Industrial Development for the Bay Area Council, Inc. since 1956. He also served as assistant vice president for the Crocker-Anglo National Bank, headed the Real Estate Loan Department and new Business Division in Sacramento. He was a director for the California State Department of Veterans Affairs and was with the Pacific Gas and Electric as assistant to the San Francisco division manager.

Callaghan was called to active duty with the U. S. Navy as an Ensign during World War II and was relieved to inactive duty with the rank of Lieutenant Commander.

The new Chief Administrative Officer will assume his duties at the Bay Area Air Pollution Control District on November 1 at a starting salary of $15,500.

Among his club affiliations are the Press and Union League Club and the World Trade Club.

The following is a statement by D. J. Callaghan upon his appointment as Chief Administrative Officer of the Bay Area Air Pollution Control District.

"I am delighted to have an opportunity to meet with the press in this informal conference so that we can become better acquainted.

"As you know, my appointment as Chief Administrative Officer has just been made, and I am in no position to discuss the District's program policy. Briefly speaking, I will say that I intend to work diligently for the program. To accomplish our purpose of air pollution control, we must work with the spirit of co-operation.

"The Board of Directors, in establishing the position of Chief Administrative Officer, has incorporated within its areas of supervision the public relations program. I wish to state to you now that I will always be available to the press at any time.

"The way the District staff is now established, the Chief Administrative Officer is charged with the responsibility of the administrative functions, as well as the formulation of the public information program. The Control Officer is in charge of the technical aspects of the District, and the Legal Counsel has charge of the legal matters. Each of these positions reports directly to the Board of Directors. It is the Board, with its representation from each of the six counties, which formulates the policies of the District. I am sure that through our joint cooperation, the District program will function smoothly."

Clifford W. Swenson of San Jose, who was appointed recently to the 20-man Advisory Council of the six-county Bay Area Air Pollution Control District, attended his first meeting with the advisory group September 27.

Mr. Swenson was named by the Board of Directors to fill the general contractor vacancy on the Council which resulted from the resignation of William Nicholson, also of Santa Clara County.

Los Angeles

"California is well along the road back to clean air." This is the encouraging word here today from Dr. John T. Middleton of Riverside, State Motor Vehicle Pollution Control Board chairman, in describing the work of the Board during National Cleaner Air Week.

"Of more dramatic and immediate concern than the conquest of outer space—if we only knew it—is California's battle to safeguard the life-supporting properties of our own atmosphere down here at the breathing level," Dr. Middleton said.

He pointed out that the effects of air pollution, stemming mainly from motor vehicles in Southern California, costs each citizen approximately $50 a year in corrosion, damage to plant life, and health.

"But California has taken positive action to reduce these dangers," Dr. Middleton said. "It is the first state to enact a control program for motor vehicle emissions. We already have approved one device for the crankcase and expect another before the end of the year.

"Exhaust control devices are more complicated, but we can look forward to the approval of at least two by the end of 1962. Then we shall begin to see and feel the difference in air quality," Dr. Middleton declared.

New York City

Significant reductions of hydrocarbons and carbon monoxide can be achieved by use of the "crankcase blowby" device on automotive vehicles, according to

(*Continued on p. 586*)

Personalia

C. Fred Gurnham, Professor and Head of the Department of Chemical Engineering, Michigan State University, has resigned from the University as of October 31. He will establish his own practice as a consulting chemical and sanitary engineer, specializing in the field of industrial waste and disposal.

* * *

Jack L. Mayfield has been named Sales Engineer for the Scientific and Process Instruments Division of Beckman Instruments, Inc., according to Paul E. Paules, Manager of the division's Western Region. Mr. Mayfield will represent the division in the sales of laboratory instruments in Northern California and Nevada.

* * *

The appointment of **John Schafer** as a sales engineer for the Scientific and Process Instruments Division of Beckman Instruments, Inc., has been announced by Robert A. Piper, Manager, Midwestern Region, for the Corporation.

Mr. Schafer will represent the division in North Chicago, Wisconsin, Minnesota, North Dakota, and Michigan in the sale of the complete line of Beckman laboratory instruments.

* * *

Don Fowler, former Chief of Industrial Hygiene for the Chrysler Corporation, has joined the Lead Industries Association. Mr. Fowler will succeed the late Manfred Bowditch as the association's Health and Safety Director. In this capacity he will be responsible for the continuing program of Lead Industries Association for gathering data and assisting in the setting of standards and acceptable practices for the industrial and domestic use of lead and lead products. He will also direct the association's activity in the several conferences, seminars, and publications which LIA sponsors or in which it participates.

* * *

The Department of Civil Engineering of the University of Illinois announces the appointment of **Dr. Ichiya Hayakawa** as Research Associate in Sanitary Engineering, effective September 1, 1961.

Dr. Hayakawa's major field of interest is air pollution and industrial hygiene. He is a member of the Air Pollution Control Association.

CONTROL DISTRICT NEWS

(*Continued from p. 585*)

results obtained in almost 600 tests run by the Bureau of Laboratory of the New York City Department of Air Pollution Control.

Commissioner Benline stated that this is the first time scientific tests of the effectiveness of the crankcase blowby device have indicated substantial reductions in carbon monoxide. Up to this time, he indicated, it had been assumed that the device was primarily effective on hydrocarbons.

The laboratory's tests began in the spring of 1960 and are continuing. It was felt that the information gathered thus far should be released to the public, in order to further substantiate the Department's position, which is supported by every other independent testing source, that the crankcase blowby device effectively controls the approximately 30% of the total pollution from a vehicle which is emitted from the front end of the vehicle and that the device results in better engine performance.

Commissioner Benline gave the following summary of the results of the Laboratory's tests:

(*1*) On the basis of the work done in this study, the "crankcase blowby" device shows definite and conclusive possibilities in the reduction of the emissions of carbon monoxide and hydrocarbons from automotive vehicles.

(*2*) The amount of reduction varies, depending on the mechanical condition of the engine and the type of device used.

(*3*) For a car in fair mechanical condition and used primarily for urban driving, this reduction may be estimated as about 40% of the total pollution from a vehicle.

(*4*) These devices, if properly maintained and serviced, not only reduce pollution, but increase the efficiency of gasoline engines in regard to fuel economy and oil stability.

(*5*) The greatest percentage of reduction by the device is at idling speeds and since, in urban areas, automotive vehicles are idling very often, this becomes of particular significance in New York City and other population centers.

"Our tests prove conclusively what we and others have been saying for a year now," Commissioner Benline said. "The crankcase blowby device works, it is inexpensive, and it saves the owner of the vehicle money in gasoline and oil. It must be remembered that our tests were conducted on older vehicles—one of them a 1953 car—and the results were consistently good. The device is available now, as optional equipment on new cars, for about $5. We are working for the inclusion of this device as standard equipment on every gasoline vehicle. The automotive industry refuses to take necessary action to protect the public from a health menace which the industry is causing. We are supporting legislation to make the device mandatory.

The New York-New Jersey Cooperative Committee on Interstate Air Pollution has called for the installation of devices to control crankcase emissions on all 1963 models of automobiles and trucks, it was disclosed by Arthur J. Benline, Chairman of the Committee.

Welcome New Members

Individual Memberships

Butts, Francis T., Boonton, New Jersey
Dolza, John, Fenton, Michigan
Henry, Guy T., Providence, Rhode Island
Innes, William B., Stamford, Connecticut
Köhler, Albert, Worms (RH), West Germany
Leibe, Wendel G., New Orleans, Louisiana
Marion, Gerard N., New York, New York
Marks, John C., Anchorage, Kentucky
Mathews, Dean S., Cincinnati, Ohio
Millen, J. A., Los Angeles, California
Murray, Peter J., Aurora, Colorado
Weaver, Jonathan M., Philadelphia, Pennsylvania

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TRAINING COURSES TO BE PRESENTED

The Public Health Service, through its Division of Air Pollution, will present consecutive training courses, "Analysis of Atmospheric Inorganics," March 5–9, 1962 (one week), followed by "Analysis of Atmospheric Organics," March 12–23 (two weeks), at Cincinnati, Ohio. Both courses are offered for professional chemists and other scientist having laboratory or technical responsibility for sample analysis in air pollution programs.

In the first course, emphasis is directed toward analytical methods employed in determination of common air pollutants such as total particulates, lead, fluoride, sulfur compounds, nitrogen oxides, carbon monoxide, and oxidants. Problems of analysis are approached through qualitative procedures and quantitative spectrophotometric and polarographic procedures.

Info on Second Course

In the second course, emphasis is directed toward the chemical, physical, and instrumental approaches to the separation, identification, and measurement of airborne organic pollutants with coverage of recent applications of chromatography, and UV-visible and activation fluorescence spectrophotometry to polynuclear air particulates. It includes instruction in techniques employing solubility separations of mixtures of airborne particulates and infrared spectrophotometric identification, with attention directed also to procedures for collection and analysis of specific substances, to application of gas chromatography, and to consideration of criteria for methods consonant with desired precision, accuracy, and sensitivity.

Address applications for the course or requests for information to the Chief, Training Program, Robert A. Taft Sanitary Engineering Center, 4676 Columbia Parkway, Cincinnati 26, Ohio.

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SURGEON GENERAL LUTHER L. TERRY ANNOUNCES ESTABLISHMENT OF AIR-MONITORING PROGRAM

The establishment of a continuous air-monitoring program to provide vital information on air-pollution levels in American cities has been announced by Surgeon General Luther L. Terry of the Public Health Service.

Designed to provide automatic measurement and analysis of the continuously fluctuating levels of pollutants in urban air, the program is based on special air-monitoring equipment located in the center-city area of eight major U. S. communities—Chicago, Cincinnati, Detroit, Los Angeles, New Orleans, Philadelphia, San Francisco, and Washington, D. C.

Built and equipped by the Public Health Service at a total cost of $300,000, the new equipment will go into operation this fall and will provide, at the outset, automatic and continuous sampling and analysis of seven gaseous pollutants—sulfur dioxide, nitric oxide, nitrogen dioxide, carbon monoxide, ozone, total hydrocarbons, and total oxidants.

In addition to automatic gas sampler-analyzers, the stations will also house supplementary equipment to provide information on particulate pollutant concentrations, pollutants washed out of the atmosphere by rainfall, and measurements of wind turbulence at the sampling sites.

Continuous air monitoring is not intended to supplant the periodic sampling conducted by the National Air Sampling Network of the Public Health Service, which has been in operation since 1955. The National Air Sampling Network provides information, at more than 250 urban and rural sites, on average levels of particulate matter and of radiation; and, at 50 sites, on the average levels of two gases—sulfur dioxide and oxides of nitrogen.

Operated by Employees

The new continuous-monitoring stations will be operated by employees of the participating cities, all of whom have received special training at the Public Health Service's Robert A. Taft Sanitary Engineering Center in Cincinnati, Ohio. The first of the eight cities in which this operation will begin is Cincinnati, which will dedicate its station on October 23 to mark the beginning of Cleaner Air Week. The other stations are expected to begin operations within the month.

"While the National Air Sampling Network continues to be extremely valuable as a means of determining trends and changes in air pollution patterns nationally," said Vernon G. MacKenzie, Chief, Division of Air Pollution, Public Health Service, "we have for a long time needed more sharply defined information on the continuously changing levels of pollutants throughout the day and night for use in our research and epidemiological studies on the health effects of air pollution. The continuous air monitoring program should eventually fill this need."

AP ADVISORY BOARD NAMED BY MAYOR IN SEATTLE, WASH.

Fourteen men and women were named by Mayor Clinton to the Seattle, Washington, Air Pollution Advisory Board.

The board, set up as part of the recently enacted air pollution control ordinance, will study control of air pollution and the administration of air pollution regulations. It also will seek practical means of measuring and controlling specific air contaminants.

Named to serve until December 31, 1961, were Edward D. Fleming, representing the American Institute of Chemical Engineers; Fairman B. Lee, the American Society of Mechanical Engineers, and Mrs. Hazel K. Bloss, Seattle Apartment Operators' Association.

Serving until December 31, 1962, will be Peter A. Breysse, representing the Environmental Research Laboratory at the University of Washington; industry; William M. Black, lumber industry; and J. A. Berg, Association of Washington Industries.

Named for terms ending December 31, 1963, are H. Wayne Kirby, representing the public; David Whitcomb, Jr., Building Owners & Managers' Association; and Theo Damm, Seattle Chamber of Commerce.

Serving until December 31, 1964, will be Richard McKay, Mrs. Arthur Lamphere, Fred S. Merritt, and Dr. Sherman M. Williamson, all representing the public.

Ex-officio members will be Dr. S. P. Lehman, director of Public Health; Fred B. McCoy, city building superintendent; and Clarence F. Massart, chairman of the City Council Public Safety Committee.

All nominations are subject to City Council confirmation. The members will act in an advisory capacity to the City Council only. The board will elect its own chairman.

ACTIVITIES, OBJECTIVES OF TR-4 COMMITTEE ARE MADE KNOWN

The TR-4 Committee on Radioactive Air Pollution has announced its activities and objectives pending approval of the APCA Board of Directors, according to W. A. Crandall Chairman. They are as follows:

(*1*) To become familiar with the nature and levels of background airborne radioactivity throughout the country.

(*2*) To keep advised of the nature and level of airborne radioactivity released from nuclear facilities, both currently in operation or being planned and constructed.

(*3*) To keep up to date on the technology of removing airborne radioactivity from plant effluent gas streams.

(*4*) To keep abreast of the various techniques and their limitations for measuring airborne radioactivity.

(*5*) To keep informed of the regulations promulgated by cognizant authorities, such as the AEC, affecting the release of radioactivity to the atmosphere.

(*6*) To furnish information and advice to regulatory bodies regarding the development of safe, simple, and workable codes pertaining to the control of airborne radioactivity.

(*7*) To assist in the dissemination of reliable information concerning airborne radioactivity to the general public in an effort to prevent unsound actions being taken by various political bodies under the pressure of uninformed or misinformed public opinion.

(*8*) To promote research and development in those areas where required by the promulgation of data on current or potential problems to those groups able to assist in their solution.

IHF HOLDS ANNUAL MEET

The Industrial Hygiene Foundation held its Annual National Meeting at Mellon Institute, Pittsburgh, Pennsylvania, October 25 and 26.

Topics on the meeting agenda covered a wide range of questions including medical, chemical, legal, management, and engineering aspects of health and safety.

Among the outstanding authorities on the program was Dr. Philip Drinker, inventor of the iron lung, who discussed the "Health Aspects of Air Pollution."

U. S. SECTION OF AIDIS TO HOST FIRST MEETING FOR SANITARY ENGINEERS AND ADMINISTRATORS

For the first time the United States section of AIDIS will be host to the 1962 meeting of sanitary engineers and public administrators of the Americas. The meeting will be held in Washington, D. C., June 10 to 15, 1962, at the Departmental Auditorium, Constitution Avenue at 13th Street, in downtown Washington. For the past 14 years these meetings have been held in Central and South American countries.

A total attendance of 400 to 800 is expected and about half will be prominent sanitary engineers from the Latin American countries. Those attending will be men of considerable professional and official stature, many of ministerial and sub-ministerial level. Simultaneous translation service is anticipated to promote full understanding of the program by all.

A strong technical program is being planned and with the support which has been forthcoming from the manufacturers, the U. S. Public Health Service, and the International Co-operation Administration, an outstanding Congress will be assured.

The following tentative schedule has been proposed:

Sunday, June 10
- Exhibits and Congress Opening

Monday, June 11
- A.M.—Presidential Report, Business, Speakers on Board Scope Topics
- P.M.—Water Resources Planning: River Basins, Metropolitan Areas, Basic Engineering

Tuesday, June 12
- A.M.—Water Supply Technology: Transmission, Distribution, Treatment, Ground Water
- P.M.—Field Trips

Wednesday, June 13
- A.M.—Wastewater Management: Collection, Treatment, Receiving Waters
- P.M.—Public Utilities Management: Administration, Finance, Planning, Education, Training Research

Thursday, June 14
- A.M.—Special Subjects: Refuse, General Sanitation, Radioactive Contaminants, Air Pollution, Industrial Hygiene
- P.M.—Free — Special Consultations Exhibits Removed

Friday, June 15
- A.M.—National Water Supply Planning, Business and Closing

An outstanding feature of the meeting will be exhibits by manufacturers from throughout the Americas. Anyone interested in exhibiting at the meeting is invited to write to John G. Stewart, Manager, Water and Sewage Works Manufacturers Association, 165 Broadway, New York 6, New York.

All interested are invited to attend. The Annual Meeting of the American Water Works Association in Philadelphia the week following will provide an added attraction to those attending the meeting.

The Willard Hotel, 12th and Pennsylvania Avenue, N.W., will be headquarters.

For further information write to:

Edmund G. Wagner
AIDIS Congress Chairman
Office of Public Health
International Co-operation Administration
Washington 25, D. C.

PHS MAKES KNOWN THE PUBLICATION OF HEALTH BROCHURE

The U. S. Department of Health, Education, and Welfare, PHS, has published a brochure intended to acquaint the scientific fraternity with either new or expanded opportunities for research—and training—in the area of environmental health; namely, air pollution, water supply and pollution control, radiological health, occupational health and industrial hygiene, and environmental engineering and food protection—under the various research grant and training programs of the Public Health Service.

Requests for brochures or additional information may be obtained by writing to Frank A. Butrico, Chief, Office of Resource Development (Environmental Health), Bureau of State Services, U. S. Department of Health, Education, and Welfare, Public Health Service, Washington 25, D. C.

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E. K. VON BRAND, P. E.
Consulting Engineer
Hopewell Junction — New York

REPUBLIC STEEL SLATES CLEAN-UP FOR CHICAGO PLANT

A 98% efficient dust clean-up is slated for the Chicago steel plant of Republic Steel Corporation where two open hearth steelmaking furnaces are being converted to the oxygen roof-lance process. Republic Steel has awarded the contract to Research-Cottrell, Inc. and Swindell-Dressler Corporation. Although the amount of the contract, including installation, is approximately $1,000,000, Republic will invest upwards of $3½-million in the over-all project, scheduled to be completed by July 1962.

The air-cleaning system being designed by Research-Cottrell, Inc., Bound Brook, New Jersey, leading U. S. manufacturer of industrial gas cleaning equipment, will handle 300,000 cubic feet of gas per minute at a temperature of 550°F with an efficiency of 98%. The system will be installed by Swindell-Dressler Corporation, Pittsburgh, Pennsylvania.

Fumes and dust particles down to sub-microscopic size will be removed by the Cottrell precipitator from the furnace gases. Silicon rectifiers and the Cottrell automation system will be incorporated in the new system to maintain economic and efficient control of the electrostatic precipitator at all times.

Electrical precipitation is based somewhat on the same principle as attracting scraps of paper to a comb rubbed on a cloth. Industrial precipitators use a high-voltage discharge to put a positive or negative charge on the particles in a gas stream. The charged particles then pass through a high intensity electrical field and are drawn out of the gas stream by attraction.

Electrical precipitation is widely used to control smoke from electrical power stations, paper mills, cement plants, chemical processes, and other industrial plants. It has been used in the steel industry for a number of years in connection with the cleaning of blast furnace gas prior to its use as a fuel in power houses, coke ovens, etc. The technique has only recently been used in controlling emissions from open hearth furnaces using the oxygen lance process, conditions of which are considerably different from those in the cleaning of blast furnace gas.

In Memoriam . . .

We regret to announce that William V. Garretson, director of the Perth Amboy Bureau of Air Pollution Control, died October 16.

LETTERS TO THE EDITOR

(*Continued from p. 546*)

public to the increasing seriousness of the air pollution problem.

The Department of Health, Education, and Welfare shares your concern about this problem. Today, a larger population, expanding industry, and more motor vehicles have increased the sources of air pollution. Estimates of the yearly economic losses it causes go up accordingly and continuing research conducted or sponsored by the Public Health Service tends to confirm our suspicions of its harmful effects on human health.

There is no doubt that we need to learn still more about the nature and effects of air pollution and to develop more effective means for controlling it. We also need to apply—much more widely than we do at present—what we already know. By spotlighting public attention on this problem during Cleaner Air Week, your committee contributes importantly to its solution.

ABRAHAM RIBICOFF, Secretary
Health, Education, and Welfare

Dear Mr. Howison:

The efforts of the Air Pollution Control Association to focus attention on the problems of air contamination through an annual observance of Cleaner Air Week deserves broad support by all Americans.

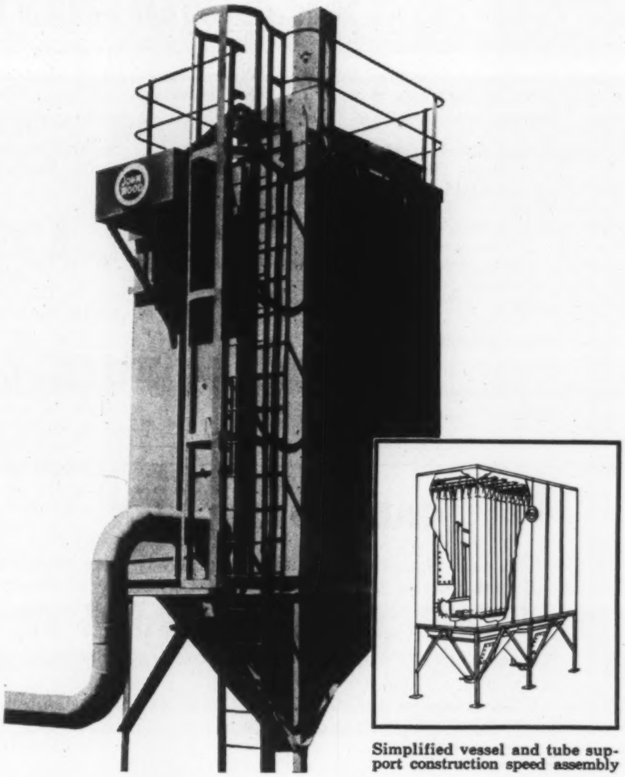
Since none of us has found an acceptable substitute for breathing, we should all have a deep interest in the quality of the air we breathe. Unfortunately we do not know how to translate this interest into action. It is through the good work of your organization that public understanding is enlisted behind effective community-wide approaches to air pollution control.

Accordingly, I am pleased to play what part I can in encouraging public support of your efforts to conserve one of our most precious assets—the air we breathe.

LUTHER H. HODGES,
Secretary of Commerce

Proceedings of the Second Technical Meeting of APCA's West Coast Section are available. Prices are as follows: $1.00 to West Coast Section members, $1.50 to other APCA members, and $2.00 to nonmembers. For Proceedings write to: Robert G. Lunche, 434 S. San Pedro Street, Los Angeles 13, California.

New Ideas On Dust And Fume Control



Simplified vessel and tube support construction speed assembly

New Products:

John Wood High Efficiency Fabric Filter

John Wood Fabric Filters are engineered for 99.9% efficiency in addition to trouble-free operation. They are the result of a program to design equipment for fully effective removal of all dry dusts at elevated operating temperatures.

An extremely varied group of filter sizes, shapes and types is available in capacities from 100 CFM to 48,000 CFM. Larger volumes are handled through a combination of units. John Wood automatic reverse flow mechanisms or shaker assemblies assure proper and gentle cleaning of fabric. Tubular or envelope bags are made of cotton, orlon, dacron, nylon or glass to meet any requirement.

New Engineering: John Wood Fabric Filters are but part of the complete line. Other equipment includes Interphase Reaction Scrubbers, Multi Cyclones, Involute Cyclones, Venturi Scrubbers and combination units. New designs are now under development.

New Service: John Wood Air Pollution Control is fully programmed from analysis of existing conditions to equipment installation. Frequently economies result that make the installation self-liquidating through lower maintenance and replacement costs.

Write for engineering assistance or specific product information. An air pollution preliminary analysis kit is available without obligation.

QUALITY PRODUCTS JOHN WOOD SINCE 1867

AIR POLLUTION CONTROL DIVISION
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Provisional Program for New South Wales Clean Air Conference*

MONDAY, FEBRUARY 19

8:45 Registration
10:15 Official Opening by The Hon. W. F. Sheahan, Q.C., Ll.B., Hon. D.Sc., M.L.A., Minister for Health
11:00 Morning Tea
11:30 Technical and Legal Aspects of New South Wales Clean Air Act, Dr. J. L. Sullivan, M.Sc., Ph.D., Occupational Health Division, N.S.W. Dept. of Public Health
12:45 Lunch
2:15 Overseas Guest Speaker, Mr. W. A. Damon, C.B.E., B.Sc., M.I.Chem.E. Former Chief Alkali Inspector, Dept. of Housing and Local Govt., U.K.
3:15 Afternoon Tea
3:45 Overseas Guest Speaker, Dr. M. Katz, M.Sc., Ph.D., Director, Environmental Assessment, Occupational Health Division, Dept. National Health and Welfare, Ottawa, Canada
4:45 Session Ends
6:30 Cocktails
7:00 Official Dinner (dress informal)
8:00 Films

TUESDAY, FEBRUARY 20

First Technical Session
9:15 Evaluation of Pollution
Second Technical Session
11:15 Effects of Pollution
12:45 Lunch
Third Technical Session
2:15 Meteorology & Atmospheric Dispersion
Fourth Technical Session
4:00 Control of Pollution (Legal)
5:00 Session Ends

WEDNESDAY, FEBRUARY 21

Fifth Technical Session
9:15 Control of Pollution (Solids)
Sixth Technical Session
Control of Pollution (Gases)
12:45 Lunch
Seventh Technical Session
2:15 Control of Pollution (Combustion)
Eighth Technical Session
4:00 Control of Pollution (General)
5:00 Conference Ends

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* Accommodation at Basser College, University of New South Wales, will be available.

CALENDAR

February 19–21	Clean Air Conference, sponsored jointly by New South Wales Department of Public Health and University of New South Wales, at the University of New South Wales, Sydney, New South Wales.
May 20–24	55th Annual Meeting of APCA, Chicago-Sheraton Hotel, Chicago, Illinois.
June 10–15	VIII Congress Inter-American Association of Sanitary Engineering, Departmental Auditorium and the Willard Hotel, Washington, D. C.

OFFICERS FOR THE EAST CENTRAL SECTION

NEW OFFICERS—*Newly elected officers of the East Central Section discuss day's activities with Meeting Chairman Ralph W. Bourne (**third from left**). They are from left: Paul D. Findlay, secretary treasurer; Albert Locuoco, chairman; and Wright Erion, vice-chairman.*

ACQUISITION TOLD

Acquisition by Wheelabrator Corporation of Mishawaka, Indiana, of the W. W. Criswell Company, Inc., of Riverton, New Jersey, manufacturer of filtration products, has been announced by Harold M. Miller, senior vice president of Wheelabrator.

The Criswell Company produces all types of fabricated bags and blankets for filtering solids from gas or liquid streams. The cloths are made from natural (cotton and wool) and synthetic (glass, nylon, orlon, dacron, etc.) fibers.

Mr. Miller said the present management, headed by W. W. Criswell, Jr., president and founder, will continue to operate the New Jersey company.

Criswell's products are supplied to many industries principally in the cement, steel, chemical, carbon black, mining, and nonferrous metals fields.

The acquisitions of Criswell will compliment products of Wheelabrator which manufactures dust and fume collection equipment. Wheelabrator is a subsidiary of Bell Intercontinental.

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Boston—Washington—New York

CONVENTION ISSUE

of

APCA JOURNAL

Is Scheduled for

APRIL 1962

All Ads Must Be in by February 1, 1962

OPEN FOR SUGGESTIONS

The time is fast approaching when a new president and six new APCA Directors will be elected by the membership. You, as an individual member or company representative member of APCA, are requested to submit to the chairman or any member of the Nominating Committee, names of individuals and the offices for which you feel they are qualified. These recommendations should be received before March 1, 1962.

The members of the Nominating Committee and their addresses are as follows:

V. G. MacKenzie, Chairman
Chief, Division of Air Pollution
U. S. Dept. of HEW
Public Health Service
Washington 25, D. C.

Dr. C. A. Bishop
United States Steel Corp.
525 William Penn Place
Pittsburgh, Pennsylvania

L. B. Hitchcock
Lauren B. Hitchcock Assoc.
60 E. 42nd Street
New York 17, New York

H. M. Pier
9 Sunnybrook Road
Basking Ridge, New Jersey

F. R. Rehm
Department of Smoke Regulation
Milwaukee, Wisconsin

V. H. Sussman
Dept. of Health
Chief,
Air Pollution Control Section
Div. of Industrial Hygiene
P. O. Box 90
Harrisburg, Pa.

The offices for which this committee is to select nominees are:

1. President—to serve one year.
2. Six Directors—to serve according to the following schedule:
   Two control officials to serve three years.
   One representative from research, educational, and consultant category to serve three years.
   Three industry representatives, two to serve three years and one to serve one year.

Retiring Board members are: Harry A. Belyea and Charles W. Gruber, control officials; R. L. Ireland, L. W. Cadwallader, and Roger W. Hooker, industry; and V. G. MacKenzie, research, educational, and consultant category.

RESOURCES RESEARCH INC.

Louis C. McCabe, President

Problems concerning man's environment, his use of it and its relation to his health and economy encompass our sphere of activity.

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Team the Beckman® GC-2A Gas Chromatograph, ThermotraC, and Flame Ionization Detector for greater resolution and faster analyses!*

Combine the Beckman GC-2A, most reliable gas chromatograph – the Beckman Flame Ionization Detector, most sensitive flame ionization detector commercially available – the Beckman ThermotraC, newest, most versatile temperature programmer. You'll get faster, more complete analyses with unmatched sensitivity and resolution. This Beckman threesome can solve any analysis problem in gas chromatography. Learn more about this new team. See your Beckman laboratory apparatus dealer, or write direct for Data File 85-12-04.

BECKMAN GC-2A GAS CHROMATOGRAPH. The most sensitive instrument with a thermal conductivity detector – capable of detection to one-half part per million. Features built-in stability, fast response, high resolution – for research work or routine analyses.

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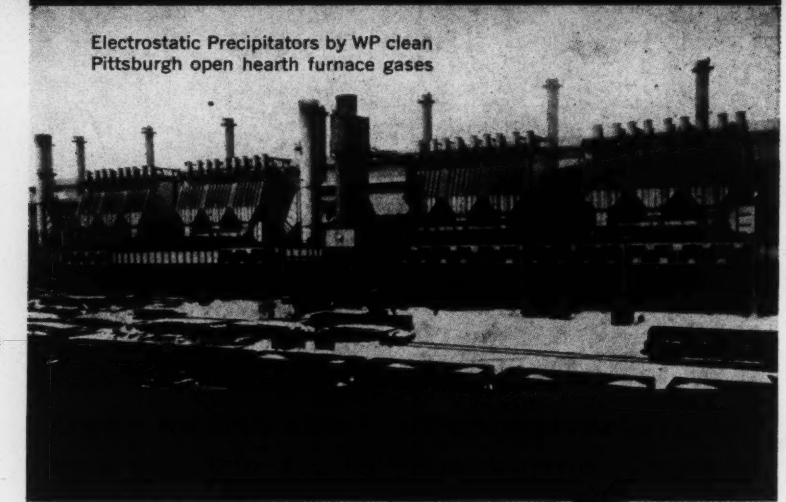
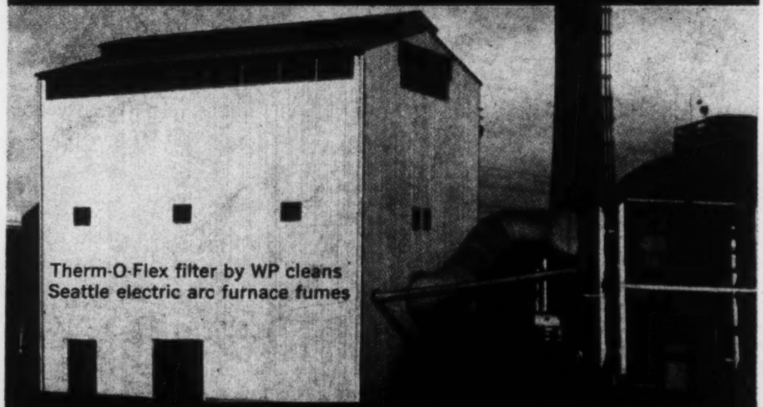


Electrostatic Precipitators by WP clean
Pittsburgh open hearth furnace gases



Therm-O-Flex filter by WP cleans
Seattle electric arc furnace fumes

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